5-12

United States Department of the Interior
WATER AND POWER RESOURCES SERVICE
~~BUREAU OF RECLAMATION~~
LOWER COLORADO REGIONAL OFFICE
P.O. BOX 427
BOULDER CITY, NEVADA 89005

IN REPLY REFER TO: LC-751
453.

1980

To: All Interested Individuals

The initial planning meeting for the special study *Water Conservation Opportunities, Imperial Irrigation District, California* is scheduled for August 19, 1980, at 9 a.m. in the Administration Building Conference Room of the Water and Power Resources Service in Boulder City, Nevada. All agencies who are interested in participating on the planning team and/or can provide input to the study are encouraged to attend. The enclosed agenda and plan of study are provided for your review.

Sincerely,

Roy D. Gear

Roy D. Gear
Acting for ~~Eugene Hinds~~
Regional Director

Enclosures

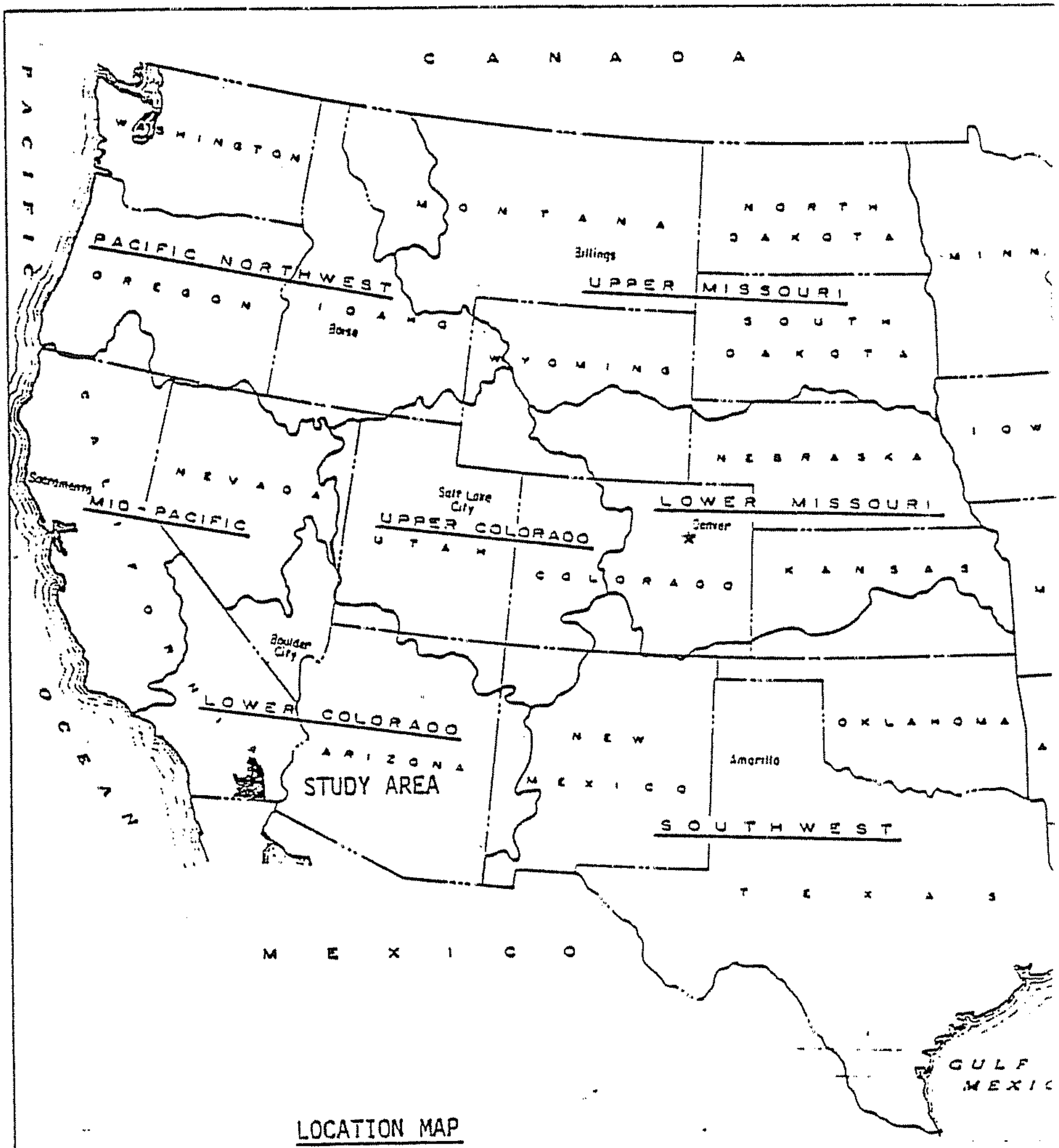
Water Conservation Opportunities
Imperial Irrigation District
Initial Planning Meeting
9 a.m., August 19, 1980
Administration Building Conference Room
Water and Power Resources Service
Boulder City, Nevada

Proposed Agenda

1. Introduction
2. Slide Presentation
3. Discussion of Plan of Study
4. Expression of Interest and Involvement in Study
5. Assignment of Team Members and Subteams

WATER CONSERVATION OPPORTUNITIES
IMPERIAL IRRIGATION DISTRICT

PLAN OF STUDY
August 8, 1980



LOCATION MAP

Water Conservation Opportunities, Imperial Irrigation District

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DEPARTMENT OF THE INTERIOR

WATER AND POWER RESOURCES SERVICE

NOTICE OF INITIATION OF INVESTIGATION

Name of Investigation: Water Conservation Opportunities, Imperial Irrigation District, California.

Location of Investigation: Imperial County, southern California.

Date Investigation Initiated: October 1979. Probable Date of Completion: June 1983.

1. Scope of the Investigation: This study will examine the potential for water conservation in the Imperial Irrigation District in southern California. The study will seek to develop an action plan, both structural and nonstructural, to obtain optimum water utilization within the existing legal, institutional, and environmental constraints.

2. Nature of Problem Involved: Present diversions to the 449,000-acre Imperial Irrigation District average about 2.9 million acre-feet per year, of which about 860,000 acre-feet are lost to nonbeneficial uses. Most of the water not consumptively used by the crops returns to the Salton Sea and cannot be reused in the Colorado River Basin.

70.3% E

includes tile H_2O

3. Public Involvement: Close coordination will be required with Imperial Irrigation District throughout the study. In addition, public meetings will be held as the study progresses at which time interested agencies, organizations, and individuals may present their views.

4. Prospective Solutions: A potential water conservation of up to 350,000 acre-feet is indicated by preliminary studies. This study will examine ways to expedite or assist Imperial Irrigation District's water conservation program through such measures as canal and lateral lining programs, tailwater reuse, system automation, providing an irrigation scheduling program, and lining onfarm ditches.

I. INTRODUCTION

A. Purpose of Plan of Study

The purpose of this Plan of Study is to provide in one document an overview of the Water Conservation Opportunities, Imperial Irrigation District Planning Study, to show what the goals and objectives of the study are, and how these goals and objectives will be accomplished. The Plan of Study is a dynamic document which will be revised from time to time during the course of the investigation as conditions change.

B. Purpose and Authority of Investigation

The purpose of this investigation is to examine the existing water conservation opportunities, wastewater reclamation potentials, and potential improvements in facilities and operations which would result in more efficient use of water in the Imperial Irrigation District located in Imperial County, California. This investigation is authorized under the Reclamation Act of 1902, as amended. It is a special investigation which will be conducted at the appraisal level. If all or certain aspects of this study show promise as a Federal initiative, a report will be made recommending a feasibility investigation be undertaken. Results of the feasibility investigation would determine if a recommendation should be made to Congress for authorization and construction of any needed facilities.

C. Study Administration and Responsibilities

The Water and Power Resources Service (Service) is responsible for planning, designing, constructing and operating irrigation projects and other water resources projects. The Lower Colorado Regional Office will be responsible for managing this study. The planning process for an appraisal study begins with a request for investigation and subsequent funding approval. Once funding is approved a Notice of Initiation of Investigation is provided to the public and all interested agencies. A preplanning conference is then held with planners from the Engineering and Research Center and the Washington Office to review the proposed study and to establish coordination channels.

Following this a Service planning team is formed comprising representatives of the Regional Office who will be performing the actual study. The study team is managed by a team leader. Subteams are formed as necessary to perform specific tasks. Public involvement is an integral part of planning involving interested agencies and individuals periodically to keep people informed of latest developments, and to assist in identifying problems and needs, and possible solutions.

The planning team, with assistance from interested agencies and the public will then identify the project needs and formulate alternative plans to be considered in the study, both structural and nonstructural. Following public review and input, formulation of alternative plans is finalized. From the data collected during the study, an action plan is developed to meet the practical beneficial use of water in the District. At this point, a decision must be made by the Service whether there are viable alternatives warranting feasibility study. If there is, the appraisal report is used to recommend to Congress and the public that a feasibility study be undertaken. If there is no viable alternative, the conclusions in the appraisal report so indicate and the study is concluded.

D. Description of the Project Area

Water is diverted from the Colorado River at Imperial Dam through the All-American Canal to irrigate approximately 449,000 acres in the Imperial Valley in southern California. Imperial Irrigation District was organized in 1911 and has been in continuous operation since that date. The All-American Canal System, consisting of the Imperial Dam and Desilting Works, the 80-mile All-American Canal, and the 123-mile Coachella Canal and appurtenant structures, began delivering irrigation water in 1940. The Imperial Irrigation District operates and maintains the headworks and desilting basins, the clay-lined All-American Canal, 1,627 miles of laterals, of which 737 miles are concrete lined, and 1,453 miles of drains. Water conveyance management and onfarm management are considered to be well above average for a gravity irrigation system. Irrigation efficiencies as computed by dividing the estimated crop consumptive use by the net supply to the District are the highest of all irrigation districts in the Lower Colorado Region. Excess irrigation water, or tailwater, is collected in waste boxes in the fields and conveyed to the drain. Drainage from the District is conveyed by tile drains in the fields to drain channels to the Salton Sea.

E. Background Data

The 1977 drought covering most of the western United States focused attention on water supplies and water conservation. Pursuant to the Emergency Drought Act of 1977 (Public Law 95-18), the Water and Power Resources Service (formerly the Bureau of Reclamation) and the Bureau of Indian Affairs completed a study identifying Federal projects having potentially attractive opportunities for conserving irrigation water supplies. The report included the Imperial Irrigation District as one of the study areas. Rough estimates indicate that about 350,000 acre-feet could be saved through reduced diversions. The General Accounting Office made a study of Federal irrigation projects which emphasized the need to improve irrigation systems for water conservation. The President's new water policy also stresses water conservation. In 1976 the Imperial Irrigation District Board adopted a 13-point water conservation program with the goal of encouraging the beneficial use of water to the fullest extent and the prevention of waste or unreasonable use or unreasonable methods of use. In June 1980 the Board adopted a new 21-point program for water conservation.

There has been continual concern over the rising water levels of the Salton Sea, a lake with no outlet fed by irrigation drainage from Imperial and Coachella Valleys, the Mexicali Valley in Mexico, sewage effluent from Mexico, and natural runoff from precipitation in the basin. State and local entities have repeatedly expressed the urgent need to identify and implement water conservation measures.

As a result of the foregoing events and concerns, the Service introduced this special study in 1978 to be included in the 1980 budget.

F. Current Activities

Investigations were initiated in fiscal year 1980. The first year has a low funding level aimed primarily at getting the program underway, developing a plan of study, evaluating the existing system, identifying water conservation opportunities to be studied, and establishing the legal, institutional, and environmental constraints of the program. The Notice of Initiation of Investigation was sent out in February 1980, the planning conference meeting and a Regional Office planning team meeting were held in March 1980. An initial meeting for all interested agencies is scheduled for August 19, 1980.

The Soil Conservation Service has been active in water conservation activities im Imperial Valley for many years and has an office in El Centro. Their expertise will be solicited during the course of the study.

The California Department of Water Resources is conducting a study of water conservation in the Imperial Valley. In order to avoid duplication of work or overlapping, the data and results of that study will be incorporated into this study and included in the final report.

II. STUDY ORGANIZATION

The study will be conducted under the direction of the Service, and it will be aided by a multidisciplinary planning team, a professional services contractor or contractors, and the general public. The specific function of each is described in the following paragraphs:

A. Lead Agency

The Service will serve as the lead agency for the study. That agency will be responsible for administering the funds allotted to the study and scheduling the various study activities. It is responsible to the Secretary of the Interior for program performance. The Service will organize and provide leadership to the planning team. It will schedule and solicit participation in public involvement activities. It will supervise the professional services contracts to ensure technical adequacy. The final report for the study will be prepared by the Service.

B. Planning Team

A planning team will be organized as provided by the Principles and Standards and Water and Power Instructions. The team will be multiobjective in scope and multidisciplinary in participation. It will be composed of representatives of interested Federal, State, and local agencies; business firms; independent organizations; and concerned individuals.

Participation on the planning team will require a substantial amount of time (possibly full time) and must be available for work sessions when they are needed, which may be on a daily basis.

The Fish and Wildlife Service will be funded for its required involvement under the Fish and Wildlife Coordination Act. Other agencies will participate under their own funding.

The Service will provide the leader for the team, and a report writer from that agency will serve as team secretary. The team will be divided into specialized subteams which will function as separate entities but each will remain responsible to the rest of the team. Possible subteams include engineering, hydrogeology, land use, economics, recreation, biology, sociology, and cultural resources. Team and subteam members will be selected from those expressing interest in the study, and a willingness to participate. In addition to the team leader and secretary, the lead agency may have active representatives on each subteam but they will not necessarily serve as subteam leaders. Participation at the subteam level will require attendance at several meetings a month or year and possibly some work assignments.

The team or any of the subteams will conduct investigations as necessary and make recommendations to the Service for appropriate action. The team will seek public input into alternative plan formulation and evaluation, and recommended plan selection. It will provide input and recommendations to the lead agency for report preparation and review.

C. Professional Services Contractor

Professional services contractors may be used and would be selected by the Service from highly qualified firms, institutions, or consortium of firms and/or institutions for several aspects of the investigation as discussed in Chapter III. The contract or contracts will be administered by the Service. The Service will review all reports submitted by the contractor and will monitor the accuracy and determine the adequacy of all data presented.

D. Public

The role of the public in the study will be to assist in identifying problems and needs and possible solutions. Opportunities will be provided for individuals from the public sector to serve on the planning team.

The public will be kept informed through public meetings, use of brochures, and by personal contact with team members. Among the public meetings that will be held are alternative plan(s), and plan selection. The public will have the opportunity to review the report as discussed in Chapter IV.

III. PROPOSED STUDY PLAN

There are four main sources of wastewater in the Imperial Irrigation District, namely (1) canal seepage, (2) canal and lateral operational wastes and spills, (3) farm tailwater, and (4) tile drainage. Possible preventive measures for each of these sources are, respectively, (1) canal lining, seepage recovery, (2) management changes, regulating reservoirs, automation or remote control, (3) irrigation management services, regulating reservoirs, management changes, automation or remote control, and (4) drainage water reuse and pumpback systems.

The study has been divided into several program elements which will be examined independently. If one or more of the elements are found to be feasible, a special report will be prepared recommending a feasibility study begin on those elements. Some other methods for conserving water in the Imperial Irrigation District may be identified as the study progresses. These methods will be considered along with the other conservation measures. The program and budget for the study are shown in Figure 1. The following is a brief description of each study element:

A. System Improvement (items 1 and 2 on Figure 1)

This includes looking at the overall system to see if water savings can be achieved by changing system management methods, installing some form of system automation, and/or installing regulating reservoirs.

It may be possible to reduce operational discharges to wasteways in the canal and lateral systems through changes in system management. Travel time from Imperial Dam to farm turnouts ranges from 8 to 24 hours; as a result, changes in water orders must be anticipated. Response of the canal and distribution system to these changes delays reaction time.

The present system has approximately 20 remote control gates. Improvements in automation technology after installation of the present system may offer potential water savings. There may be a need to provide more check structures to improve control of water flowing

Figure 1

3/7/80

PROGRAM AND BUDGET

for

WATER CONSERVATION OPPORTUNITIES

IMPERIAL IRRIGATION DISTRICT

ITEM	COST	FY1980	FY1981	FY1982	FY1983
		ONDJFMAMJJAS	ONDJFMAMJJAS	ONDJFMAMJJAS	ONDJFMAMJJA
1. System Automation	77,000				
2. Regulating Reservoirs	50,000				
3. Canal Seepage	95,000				
4. On-Farm Measures	159,000				
5. System to Collect & Reuse Wastewaters	60,000				
6. Effects of Project	151,000				
7. Use of Saved Water	70,000				
8. Report	40,000				
9. Overall Management	138,000				
Total	840,000	50,000	455,000	265,000	70,000

through the system. A wide variety of automation and remote control schemes is available. The methods of control vary greatly in cost which coupled with the potential savings in water will indicate whether system automation can be recommended for water conservation. The design of a suitable automation system will either be completed in the Engineering and Research Center or under contract.

Imperial Irrigation District has installed two small regulating reservoirs within the District. These reservoirs have been constructed on canal drops so that no pumping is required to fill or empty them. It is estimated that reservoirs save 20,000 to 30,000 acre-feet of water per year. There are several other potential sites for regulating reservoirs which will be investigated. Additional sites for low-head hydropower units at drop structures will also be evaluated.

B. Canal Seepage (item 3)

As reported in the Water Conservation Opportunities report, the difference in flows measured at Drop 1 and sum of deliveries to the farms (adjusted for spills and other uses) indicates a canal and lateral loss of about 275,000 acre-feet per year (see Figure 2). It is estimated a savings of about 150,000 acre-feet per year could be achieved through seepage prevention by lining some of the canals and laterals in the Imperial Irrigation District.

It will be necessary in this study to isolate these losses to specific canals by analyzing existing flow measurements and possibly making sole ponding tests on specific reaches of canals and laterals.

The District has a program of recovering canal seepage from the East Highline Canal through the use of interceptor pipes paralleling the canal. This program will be evaluated to determine effectiveness and applicability elsewhere in the District as an alternative to lining, particularly with regard to the main canals.

The costs and methods of canal lining will be investigated which will be used in an economic analysis of the program. Weed control, especially hydrilla, may be enhanced by canal lining.

Figure 2
Water Budget
for
Imperial Irrigation District
Based on 1972-1976 Data

Units: 1,000 acre-feet

Present		Projected
2932.0	Net Supply	2581.9
- 4.2	Main Canal Waste	- 4.2
- 147.4	Main Canal Losses (80.8 savings)	- 66.6
2780.3	Delivered to Laterals	2511.1
- 4.0	Lateral Waste	- 4.0
- 129.3	Lateral Losses (68.0 savings)	- 61.3
- 32.2	Non-Irrigation Deliveries	- 32.2
2614.8	Delivered to Farms	2413.6
-2039.8	Consumptive Use	-2029.8
575.0	Ditch and Field Loss	373.8
- 261.5	Ditch Loss (est. 10%) (152.3 savings)	- 109.2
313.5	On-Farm Deep Percolation (48.9 savings)	264.6

80,000 acre ft. - Doesn't include A.A. Canal

Total Savings = 350.0

Is Leach fraction high or low

C. Onfarm Efficiencies (item 4)

It is estimated that about 575,000 acre-feet of water is not u by the crops of the total 2,600,000 acre-feet delivered to farms. large portion of this excess water is necessary for leaching salts from the soils, and the remainder is tailwater and onfarm ditch losses. Over 2,000 miles of onfarm head ditches are now concrete lined. Preliminary estimates indicate potential savings of up to 150,000 acre-feet per year by lining the remaining ditches, 24,000 acre-feet by reorienting and dead-leveling fields, and 25,000 acre-feet by some form of onfarm irrigation management technical services.

Although the present onfarm efficiency of 78 percent for the Imperial Irrigation District is the highest in the Lower Colorado Region, it may be possible with the indicated changes to increase the efficiency to 85 percent. According to recent studies by the Science and Education Administration in Riverside, California, this efficiency is still low enough to provide an adequate leaching requirement. This aspect will be examined further in the study.

Additional data to firm up these estimates of water disposition on farm must be collected. This data collection effort may be combined with a demonstration of the Irrigation Management Services program with some cooperating farmers in the District.

The present irrigation system has tile drains and waste boxes which collect and convey drainage and tailwater to the drainage system. It may be possible to install some form of tailwater reuse by either pumping tailwater to the next field or back to the canal for further use downstream.

The California Regional Water Quality Control Board has adopted a Water Quality Control Plan for the West Colorado River Basin Region which identifies the use of sediment retention basins and pumpback systems as practices which may improve the water quality in agricultural drains. Pumpback systems may also help water conservation. The Regional Board intends to construct a pilot project within the Imperial Valley to test those systems under local conditions, but presently lacks funding.

D. System to Collect and Reuse Wastewater (item 5)

As an alternative or possibly in addition to reusing tailwater, a separate conveyance system of pipelines and reservoirs could be used to collect tailwater, spills, and other wastewaters before being combined with drainage water and pumped or conveyed back to the irrigation system. In addition, there may be a means of collecting brackish drainage water before it flows into the Salton Sea by using it for substitution or exchange water with industrial users or powerplant cooling uses.

E. Effects of the Project (item 6)

The impacts of the identified water conservation measures will be examined. Water and salt budgets with and without the measures will be prepared. Reductions of flows of the magnitude identified by the preliminary study could have significant impacts, both positive and negative, on the Salton Sea which could affect the environment, recreation, and shoreline property. There could also be an increase in the salinity of the Salton Sea, which could hasten the demise of fisheries there.

Changes to the ground-water regimen both in the United States and Mexico will be evaluated.

Repayment of project costs will be considered. The beneficiary of the saved water will probably be expected to pay for the water, unless it is determined to be a national goal that certain efficiencies be attained with partial or total Federal nonreimbursable funding to achieve water conservation goals.

F. Use of Saved Water (item 7)

Any water made available for new uses would probably be marketable in the water-short southern California area of the Lower Colorado Region, either to meet municipal and industrial water demands in southern California or to maintain or expand irrigation within Imperial Irrigation District or other districts.

G. Constraints

The legal and institutional factors are considered to be significant. The proposed water conservation measures could change the available water supply in the Lower Colorado River and must be instituted in consideration of allocations of water now in effect. Legal and institutional problems could probably be overcome if feasible methods for significant savings are found.

IV. REPORTS

A. Reports Required

A status report will be prepared early in 1982 to evaluate progress to date and identify any potential measures which should be recommended for a feasibility level study.

At the culmination of the study, the Service will prepare a special report. The report will fully document the results of the study and identify the viable plans for water conservation in the Imperial Irrigation District. It will serve to assist the Secretary of the Interior, the President, and Congress, as well as the general public, in making decisions as to what future action, if any, should be taken. The special report will describe the area, its problems, and the resources available to correct those problems. If viable plans have been developed they will be presented in sufficient detail for evaluation, including social, economic, and environmental analysis. The report will reflect adherence to multiple objective planning at the appraisal level of detail.

Environmental statements are not required for appraisal level investigations. The special report will provide an environmental assessment in commensurate detail with other subjects covered by the investigation.

B. Report Preparation

The actual compiling and writing of the reports will be done by the Service, and that agency will be fully responsible for the content, presentation, publication, and distribution. However, appropriate data developed by the planning team, other agencies, and the general public will be used. Portions of drafts may be prepared by appropriate subteams.

As noted in the following section, the planning team will be given the opportunity to review the draft of the reports.

C. Report Review

After the drafts of the reports are submitted, a review process will follow as prescribed by Federal regulations and guidelines.

Recognizing the limitations of time and detail imposed upon appraisal investigations, but also acknowledging the need for public and interagency coordination and support, the Regional Director will coordinate field-level review of the special report by States, local entities, and the public to the extent necessary or desirable, depending on the interests involved and the need for resolution of any controversial problems.

After clearance of the completed report, the Commissioner will advise the Regional Director on field-level distribution and public release. The completed special report will include the Regional Director's recommendations as approved by the Commissioner.

V. EXISTING DATA AND PROPOSED DATA ACQUISITION PROGRAMS

A. Analysis of Existing Data

It is the intent of this study to rely heavily on data which are in existence at the present time. All agencies involved will be contacted to obtain existing data pertinent to this study. The California Regional Water Quality Control Board has indicated data are available for 11 drains in the Imperial Valley. The California Department of Water Resources has done extensive analysis of land use in the Imperial Valley, evapotranspiration drain flow measurements, and soil classification analysis. Other records from the District will be used and may be computerized, if necessary, for ease of analysis. The Science and Education Administration's research station at Brawley has been collecting data on water use and evapotranspiration which will be valuable to this study.

The existing data analyzed by the Service to date indicate some inconsistencies which should be resolved in this study. Because of the fact that consumptive use of crops and phreatophytes cannot be measured precisely, water budgets are not always precise. This was demonstrated in analysis of the water budget for Imperial Irrigation District. Two different approaches to determining water losses to the Salton Sea were used resulting in differing quantities for the various components that make up flows to the Sea. One method used the measurements of water flowing into the sea. The other method used measurements of water diverted to the District minus estimated consumptive use.

B. Need for Additional Data

Several areas in this study will probably require additional data collection. Flow measurements to determine canal and lateral losses, operational wastes and spills, onfarm deliveries, and drainage returns will be needed. Before a data acquisition program is prepared, the existing data must be evaluated further.

5-13

Doug
Welch
File 960.3

AN EQUAL OPPORTUNITY EMPLOYER

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

P. O. BOX 427
BOULDER CITY, NEVADA 89005

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U.S.MAIL

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Imperial, CA 92251

CC: (w/enc.)
Mr. Benson
Mr. Gallegos
Mr. Carter
Mr. Twogood
Mr. Wilson
Mr. Welch
Mr. Bradley

United States Department of the Interior

BUREAU OF RECLAMATION
LOWER COLORADO REGIONAL OFFICE
P.O. BOX 427
BOULDER CITY, NEVADA 89005

IN REPLY REFER TO: LC-751
453.

DEC 18 1981

Memorandum

To: Members of Planning Team and Other Interested Individuals

From: Study Team Leader

Subject: Water Conservation Opportunities, Imperial Irrigation District Special Study

A team meeting is planned for the subject study at 10 a.m. on January 5, 1982 at the Imperial County Airport conference room. Enclosed is a proposed agenda for the meeting. Also enclosed for your review and comment are minutes of the September 29, 1981 meeting, a draft of the canal seepage study, and a draft of the wastewater collector study. Please be prepared to discuss the items on the proposed agenda.

DAVID P. OVERVOLD

Enclosures

WATER CONSERVATION OPPORTUNITIES
Imperial Irrigation District
Planning Meeting
10 a.m., January 5, 1982
Imperial County Airport Conference Room

Proposed Agenda

1. Status of Planning Study
2. Additional Comments on Salton Sea Operation Study
3. Canal Seepage Study Comments
4. Wastewater Collector Study Comments
5. Status of Imperial Irrigation District Water Conservation Activities
6. Status of California Department of Water Resources Investigation
7. Status of U.S. Fish and Wildlife Service
8. Next Meeting

WATER CONSERVATION OPPORTUNITIES
IMPERIAL IRRIGATION DISTRICT, CALIFORNIA
MINUTES OF SEPTEMBER 29, 1981 PLANNING TEAM MEETING

The meeting was held at the Imperial County Airport Building, County Conference Room, and was called to order at 10:10 a.m. An attendance list is attached.

Comments on the draft Salton Sea Operation Study Report were requested. The subsequent discussion focused on a number of topics.

It was recommended that acceptable water level elevations and salinity concentrations for the Salton Sea (Sea) should be identified and a water level elevation and salinity concentration capable of satisfying the broadest possible number of interests should be determined.

An inquiry was made about why 350,000 acre-feet were used for water savings. The 350,000 acre-foot potential water savings figure was based on the corresponding figure found in the Water Conservation Opportunities, Special Report, September 1978 and would indicate the maximum effects. With water conservation, the current salinity concentration of inflows to the Salton Sea, which is about 3,000 mg/L, would increase to about 4,500 mg/L. A suggestion was then made that the Salton Sea ecosystem be evaluated. The point was made that the objective of this study was to analyze the potential for water conservation in the Imperial Irrigation District (District) and not to provide possible solutions for the potential conditions threatening the survival of the Sea.

The opinion was expressed that the operation study should address more specifically the immediacy of increasing salinity concentrations in the Sea and the threat posed to the existing fisheries resource. The need for additional water supplies, especially for the 15 million people in southern California, is critical and the demand for any available supplies would greatly intensify if water rationing were imposed. The formation of an interagency task force to study ways of saving the Salton Sea has been proposed by the California Department of Fish and Game.

Any changes in the irrigation efficiencies of the District would affect the Sea's water level elevations. The lands to which Colorado River water is being applied are entitled to such water. Irrigation efficiency, not Sea level elevations, is the primary concern of this study. A suggestion was made to refine the model projection so that the impacts resulting from the effects of increased salinity concentrations in the Colorado River water being delivered to the District can be determined.

The projected salinity concentrations threaten the survival of the existing fisheries resource. The single node model and mixing effects were discussed. It was pointed out that even without conservation, projected salinity concentrations would reach 60,000 mg/L by 1990.

Fish cannot propagate in concentrations greater than 40,000 mg/L. Additional water flowing into the Sea would only delay, not prevent, the inevitable destruction of the Salton Sea fisheries resource.

With or without conservation, the operation study indicates a salinity concentration greater than 40,000 mg/L. Even at 40,000 mg/L or greater, some veins of fresh water will continue to enter the Sea. The remaining fishery will survive in these areas, but at reduced levels. A suggestion was made that the Bureau review and update all previous mitigation plans keeping the multiobjective approach in mind.

No one agency has total authority over the Salton Sea area. Any improvement in water use efficiencies will cost money. The previous Administration was unwilling to provide the estimated $130 million needed to fund an adequate mitigation project. The cost of such a project today is estimated to be $200 to $300 million. Funding from the current Administration is not expected. State and local funding for such a project is doubtful. General support was expressed for the proposed task force.

The biggest change in the project area since the 1974 report has been the proposed development of alternative energy resources, especially geothermal and solar power. The effects of geothermal development would depend on the water sources used. Solar pond development would require water with a concentration of 250,000 mg/L. It was suggested that this study be expanded to assess the relationships between water conservation and alternative energy development.

The Pomeroy Report from the early 1960's predicted the death of the Sea based on projected salinities. Earlier fish plants, however, survived much longer than anticipated. The ecology of the Salton Sea has not been adequately investigated since the 1961 Fish and Wildlife report. Of the 35 species of fish from the Gulf of California originally introduced, the three which have survived have produced one of the best fisheries in the country. The Sea was originally a fresh water fishery which gradually evolved into a salt water fishery. It may now change again. Salinity increases could threaten waterfowl through the food chain. Additional water supplies will not be available to keep the Salton Sea diluted.

Mr. Kris Lal of the Department of Fish and Game made the following statements: Any one objective should not be pursued to the detriment of all other objectives. The study should consider keeping the salinity concentration below 40,000 mg/L and stabilizing the water level elevation of the Sea. However, both of these cannot be achieved simultaneously. Will the cost of water conservation be worth the loss of the Salton Sea fishery, which is a unique natural resource? These types of problems should be included in the scope of the water conservation study.

It was again reinterated that the water conservation study was not designed to solve all of the problems associated with the Salton Sea though some money is provided to the U.S. Fish and Wildlife Service for environmental studies.

The District, as it is obliged to do, is using received water beneficially. The District cannot only be concerned with the elevation of the Salton Sea. The Sea will seek its own water level elevation as determined by the irrigation efficiency of the District and evaporation from the Sea. An elevation of -235 feet would probably be ideal from the District's viewpoint and would reduce field drainage problems. The runoff contributed by the storms of 1976 and 1977 and the nine days of rain in the Palm Springs area during the winter of 1980 caused the elevation of the Sea to rise a total of 2 feet.

Dave Overvold briefly outlined investigations in progress. Water budget estimates have been formulated. About 800 miles of laterals have already been lined in the District through the District's own canal lining program. The recovery system along the East Highline Canal is recovering about 36,000 acre-feet of canal seepage per year. As part of the irrigation scheduling program, the neutron probe will be used on about 10,000 acres of land in scattered blocks throughout the District. About 50 water level recorders will be installed on individual fields to measure onfarm deliveries and tailwater flows. An additional 50 water level recorders will be installed elsewhere to measure canal and lateral spills and tailwater and drainage flows. At the present time, reservoir regulation does not appear to offer a significant potential for water conservation. However, further investigations are planned. A wastewater collector system is being investigated.

The meeting was adjourned at 12:25 p.m.

Name	Organization	Location
Dave Overvold	USBR	Boulder City, Nv.
Greg Poseley	Calif. Department of Water Resources	Los Angeles, Ca.
Robert Y.D. Chun	Calif. Department of Water Resources	Los Angeles, Ca.
Christopher S. Donabedian	Colorado River Board of Calif.	Los Angeles, Ca.
Darrell Marcus	USBR	Boulder City, Nv.
Frank E. Robinson	Univ. of Calif.	Imperial Valley Field Station, Ca.
Jim St. Amont	Calif. Department of Fish & Game	Long Beach, Ca.
Dan Chapin	Calif. Waterfowl Assoc.	Redwood City, Ca.
Douglas Welch	IID	Imperial, Ca.
B.L. Bradley	IID	Imperial, Ca.
J.R. Wilson	IID	Imperial, Ca.
R.F. Carter	IID	El Centro, Ca.
Don Twogood	IID	Imperial, Ca.
Kris Lal	Calif. Department of Fish & Game	Long Beach, Ca.
Ronald Powell	Calif. Department of Fish & Game	Blythe, Ca.
Gary Wheeler	U.S. Fish & Wildlife Serv.	Laguna Niguel, Ca.
Mike Delamore	USBR	Boulder City, Nv.
Phil Gruenberg	Calif. Reg. Water Qlty. Ctrl. Bd.	Palm Desert, Ca.
Gene Rounds	USBR	Boulder City, Nv.
Glenn Black	Calif. Department of Fish & Game	Chino, Ca.
Wayne Flanagan	USDA, Soil Conservation Service	El Centro, Ca.
Keith E. Moore	Calif. Department of Fish & Game	Imperial Valley, Ca.
Cristobal Gonzales	Calif. Department of Fish & Game	Imperial Valley, Ca.
Al Lapp	Calif. Department of Fish & Game	IWA-Finney-Ramer
Jesus R. Garcia	Calif. Department of Fish & Game	Niland, Ca. (IWA-Wister Unit)
Bonnar Blong	Calif. Department of Fish & Game	Idyllwild, Ca.
Don Cox	Farmer	Brawley, Ca.
John Benson	IID (Director)	Brawley, Ca.
Tony Gallegos	IID (Director)	Brawley, Ca.
Fred Kocks	Calif. Waterfowl	Brawley, Ca.

5-14

WATER CONSERVATION OPPORTUNITIES
Imperial Irrigation District
Planning Meeting
10 a.m., February 19, 1981
Conference Room
Imperial Irrigation District Operating Headquarters
Imperial, California

Proposed Agenda

A. Minutes of Last Meeting

B. Status of Investigations
   1. Salton Sea
   2. Canal Seepage
   3. Regulating Reservoirs
   4. Water Measurement
   5. Consumptive Use Estimates
   6. System Automation

C. Suggestions from Team

D. Decisions to be Made
   1. Salton Sea
   2. Water Measurement
   3. Other

E. Future Schedule

MINUTES OF AUGUST 19, 1980 PLANNING MEETING

The meeting was called to order by the team leader and introductions were made. The agenda and list of attendees are attached.

A slide presentation was made of the Servicewide Water Conservation Opportunities Program. Some slides of the Imperial Irrigation District and the Coachella Valley Water District were also shown. It was suggested that future meetings be scheduled in California as much as possible to avoid the justification of out-of-state travel.

Lowell Weeks stressed the importance of keeping abreast of all activities to ensure consensus as the study progresses.

The possible effects of water conservation on the Salton Sea are a concern of the group. The water level continues to rise in spite of the Imperial Irrigation District's aggressive water conservation program.

Bob Carter of Imperial Irrigation District asked what would prevent the District from implementing any water conservation measures identified in this study and using the saved water to irrigate more land, say on the West Mesa. The response was that some water conservation measures may be too costly for agricultural water users, but may be economical for municipal and industrial users.

Soil Conservation Service representatives said consumptive use estimates need to be investigated further. Soil moisture in some alfalfa fields had been measured with a neutron probe indicating little water use below a depth of 2 feet, apparently caused by tight soils. If this is widespread, consumptive use might be significantly lower than expected.

Assignments were made to the various planning teams based on member interests. Membership on the planning team will require attendance at quarterly meetings. Subteams will be formed as needed and will require attendance and monthly meetings and a commitment of time to work on various aspects of the study assigned to that subteam. Agency involvement was as follows:

Planning Team

- Imperial Irrigation District
- Coachella Valley Water District
- Colorado River Board of California
- California Department of Water Resources
- Colorado River Regional Water Quality Control Board
- Soil Conservation Service
- Fish and Wildlife Service
- Water and Power Resources Service

Hydrology Subteam

California Department of Water Resources
Imperial Irrigation District
Coachella Valley Water District
Colorado River Board of California
Water and Power Resources Service

Environmental Resources Subteam

Coachella Valley Water District
Colorado River Regional Water Quality Control Board
California Department of Fish and Game
Fish and Wildlife Service
Colorado River Board of California

Engineering Subteam

Imperial Irrigation District
Water and Power Resources Service

Land Use Subteam

Soil Conservation Service
California Department of Water Resources
Water and Power Resources Service

Farm Practices and Water Conservation

Soil Conservation Service
Colorado River Regional Water Quality Control Board
Water and Power Resources Service

Legal and Institutional Subteam

Colorado River Board of California
Imperial Irrigation District
Water and Power Resources Service

Attachments

Water Conservation Opportunities
Imperial Irrigation District
Initial Planning Meeting
9 a.m., August 19, 1980
Administration Building Conference Room
Water and Power Resources Service
Boulder City, Nevada

Proposed Agenda

1. Introduction
2. Slide Presentation
3. Discussion of Plan of Study
4. Expression of Interest and Involvement in Study
5. Assignment of Team Members and Subteams

Water Conservation Opportunities
Imperial Irrigation District
Boulder City, Nevada
August 19, 1980

Name	Organization
Christopher S. Donabedian	Colorado River Board of California
Bob Barton	Water and Power Resources Service
Ted Thee	USDA-Soil Conservation-Escondido
Douglas Welch	USDA-Soil Conservation El Centro
Gordon Mueller	Water and Power Resources Service
Gary Bryant	Water and Power Resources Service
Robert E. Yoha	Department of Water Resources, California
Robert D. Smith	Department of Water Resources, California
J. R. (Bob) Wilson	Imperial Irrigation District
R. F. Carter	Imperial Irrigation District
Don Twogood	Imperial Irrigation District
Lowell O. Weeks	Coachella Valley Water District
Tony Gallegos	Imperial Irrigation District
Gerald Moore	Imperial Irrigation District
Merle Turley	Water and Power Resources Service
Dean F. Johanson	Water and Power Resources Service
David McGillivary	Fish and Wildlife Service - California
Gary Wheeler	Fish and Wildlife Service - California
Arthur Swajian	California Regional Water Quality Control Board, Palm Desert, California

Water Conservation Opportunities
Imperial Irrigation District
Planning Study

Status Report

February 4, 1981

Water and Power Resources Service
Boulder City, Nevada

INTRODUCTION

This report presents the current status of investigations of the Water Conservation Opportunites, Imperial Irrigation District Study which is being performed by the Water and Power Resources Service. The study began in October 1979 and is scheduled for completion in May 1983. The study will identify both structural and nonstructural measures to conserve water in the Imperial Irrigation District.

A. Status of Study Elements

1. Effects on Salton Sea. The computer model used in the 1974 Salton Sea study was used as a first cut at estimating the effects of water conservation measures on the Salton Sea salinity and water level. Historic inflows into the Salton Sea from 1948 to 1979 were used for the 1980 to 2011 inflows used in this study. The order of the inflows was not changed from the historical order of occurrence. The results of this study are presented on the attached figures and tables. Figure 1 compares projected future salinities of the Salton Sea under two different scenarios. The solid line represents the case where no water conservation measures were implemented. The line with circled data points is for the case in which anticipated water conservation measures, assumed to be implemented in 1990, reduced the inflow to the Salton Sea by 350,000 acre-feet per year. The salinity of this conserved water was assumed to be 879 parts per million, the 1972 salinity standard at Imperial Dam. This resulted in an annual reduction of salt inflow of 420,000 tons. Figure 2 shows projected Salton Sea water levels for these same two conditions. Output from the operation study is listed on Table 1, without conservation, and on Table 2, with conservation. In order to maintain the level of the Sea at an elevation of -232 feet, the average amount of conservation would have to be 84,000 acre-feet per year.

2. Canal Seepage. Imperial Irrigation District flow records of canal losses for each ditchrider run in each of the six diversions are being analyzed for the 1977 to 1980 period. Seepage in the unlined portions of the canals in each of the 50 runs as well as the

main canals will be computed and ranked in order of water salvage priority based on seepage per mile of unlined canal. With canal lining cost estimates, a unit cost per acre-foot will be determined. A draft report of the canal seepage study will be available for planning team reviews by May 1, 1981.

3. Regulating Reservoirs. Data for the 1977 to 1980 period for the two existing regulating reservoirs, the Sheldon Reservoir on the Westside Main Canal and the Singh Reservoir on the East Highline Canal have been collected and analyzed on a first cut. Diversions to the Singh Reservoir average 13,400 acre-feet per year resulting in a net loss of 400 acre-feet per year. Evaporation on approximately 40 acres at 7 acre-feet per year accounts for about 300 acre-feet of this loss. The remainder is probably seepage and/or measurement error. If it is assumed that volumes of water on days when the inflow to the reservoir would have been lost as a spill had the reservoir not been used, an average of 6,000 acre-feet per year is saved. Assuming a cost of $1 million to construct another regulating reservoir, the cost of saving water with a regulating reservoir would be about $10 per acre-foot. This approach should be examined further to determine if it is appropriate. Potential sites for additional reservoirs will then be identified. Small regulating reservoirs on individual laterals will also be investigated. The regulating reservoirs study is scheduled to be completed by November 1982.

4. Water Measurements. It is estimated that about 1 million acre-feet of water not used by irrigation flow to the Salton Sea from the Imperial Irrigation District, an accurate estimate of what proportion comes from canal losses, from farm deep percolation, and from tailwater due to a lack of measurements. Estimates of deep percolation and tailwater combined have ranged from 307,000 acre-feet to 998,000 acre-feet.

There are an estimated 100 wasteways at the end of laterals which spill excess water to the New and Alamo Rivers and the Salton Sea. Another estimated 250 wasteways discharge to drains. There are an estimated 350 laterals and main canals and an equal number of drains. Assuming average field size to be 80 acres, and each field having one waste box, there are approximately 5,600 waste boxes. In all, there are about 6,650 locations that would have to be measured in order to account for all the water in the District.

A possible solution to determining the source of wasted water would be to take a representative area, say 10 percent of the land (45,000 acres), split up among seven or eight laterals scattered around the District, and record the delivery to the lateral, the spill at the end of the lateral, and the drain flow. This would take three recorders for each area for a total of about 25 recorders. The amount of tailwater would then be estimated from the drain records by subtracting a base drainage flow. The work required to install the measurement stations is anticipated to be contracted with the Imperial Irrigation District.

Another aspect of the water conservation study is to provide accurate measurements of flow deliveries to the farms. The U.S. Water Conservation Laboratory in Phoenix, Arizona run by the Department of Agriculture, Science and Education Administration has developed a new broad-crested weir which can be installed easily and inexpensively and provide accurate flow measurements. It has been suggested that a demonstration program be set up to install these devices on interested farmers' fields and provide the Imperial Irrigation District with recorders for the ditchriders to use in recording farm diversions.

5. Consumptive Use Estimates. Another major unknown in the water budget is the consumptive use of crops and other vegetation. Preliminary estimates have been made using constant annual values of consumptive use from Technical Bulletin 169 for each type of crop using acreages reported in the Water and Power Resources Service Crop Census Report.

We are also calculating consumptive use using the modified version of Blaney-Criddle method identified in SCS Technical Release No. 21, "Irrigation Water Requirements." Problems have been encountered in finding crop coefficient curves for some crops and determining the appropriate growing season.

A considerable amount of data has been collected by the Irrigation Management Services (IMS) programs in Yuma and Poston, Arizona. Daily consumptive use can be estimated fairly accurately from frequent neutron probe measurements of soil moisture. We are working on developing basic crop coefficient curves which will be used to adjust to the Imperial Valley climate using the Jensen-Haise method of consumptive use.

6. System Automation. Potential water savings by implementing additional forms of system automation will be investigated in this study. Work accomplished to date consists of determining the present status of automation in the Imperial Irrigation District. Remote water level readings are transmitted to the Imperial Operating Headquarters. Main canal gate positions can also be changed from the headquarters. Some wasteway gates and main canal gates are automatically actuated by water level changes in the canals. Laterals have no automation. Various automation systems will be considered, for applicability and economic viability. This portion of the study is expected to be completed by August 1981.

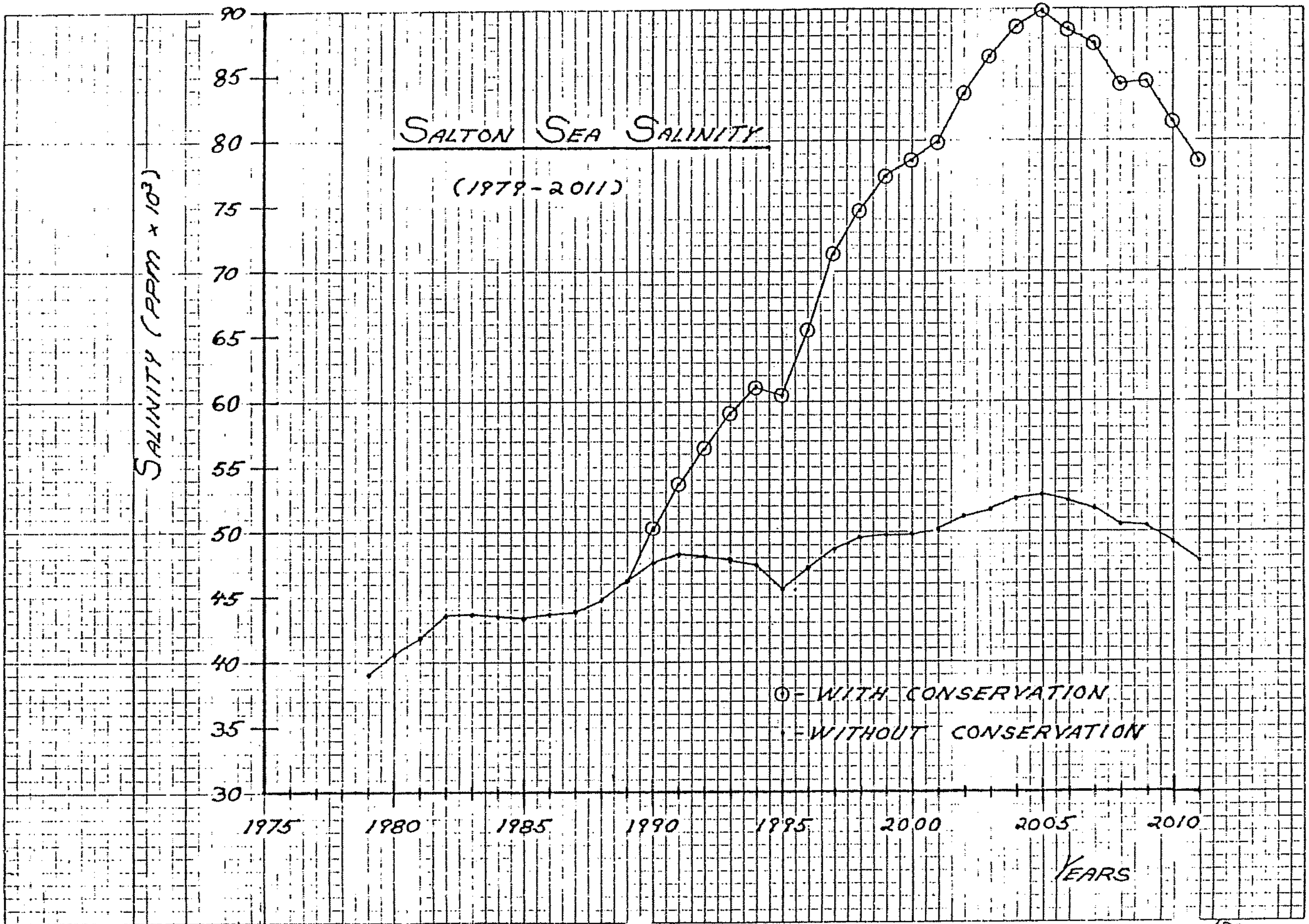

FIGURE 1

DS -/80

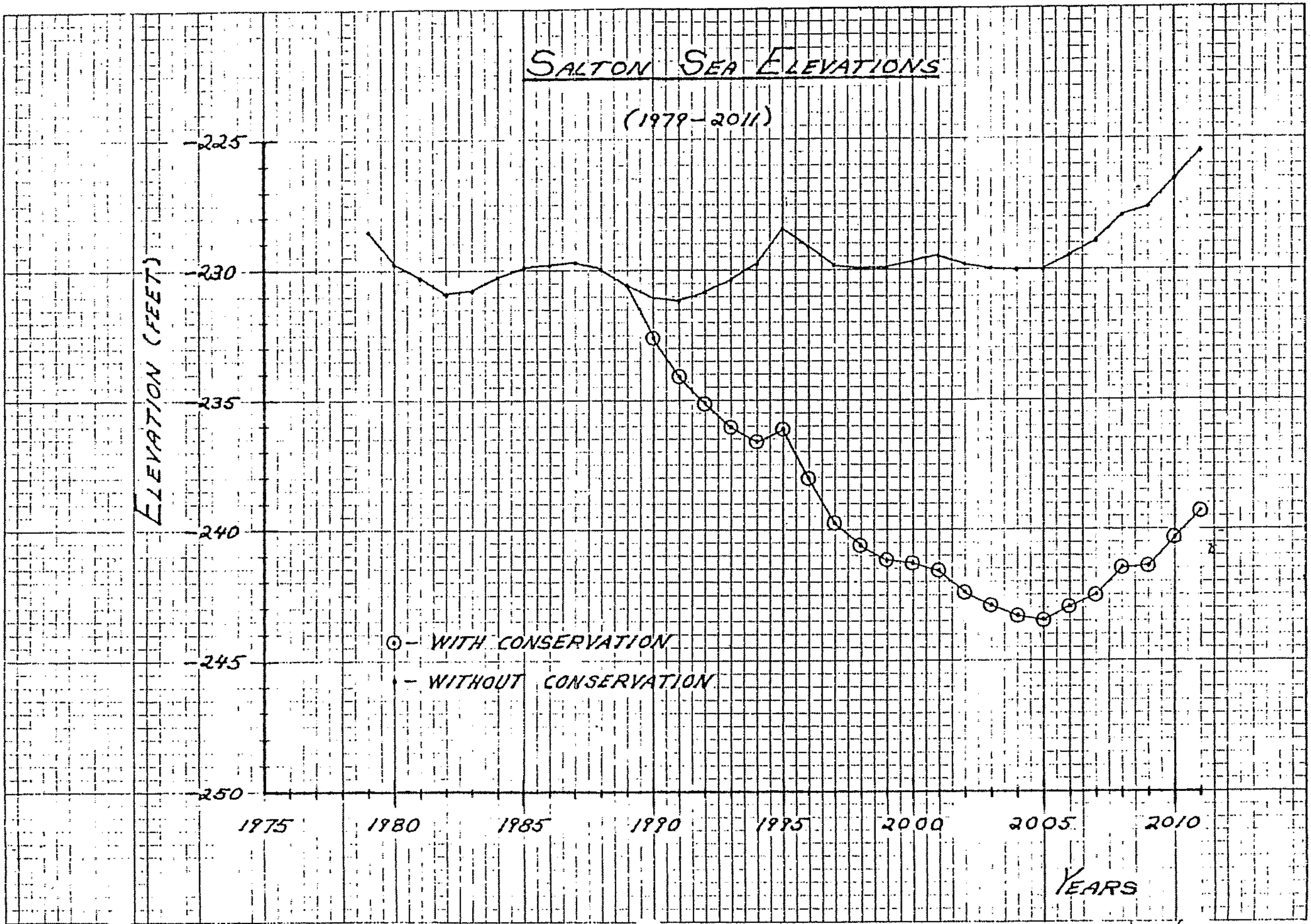

FIGURE 2

11/6/0
DS

SALTON SEA OPERATION STUDY UNCONTROLLED

YEAR	FLOWS (1000 AC FT)	PUMP	ELEV.	AREA (1000 AC.)	VOLUME (1000 AC FT)	SALT (1000 TONS)	PPM
1980	1065.	0.	-229.65	236.605	6585.625	372440.	40551.
1981	1184.	0.	-230.28	234.981	6436.827	376880.	41940.
1982	1203.	0.	-230.94	233.093	6282.602	381320.	43427.
1983	1358.	0.	-230.76	233.621	6325.751	385760.	43627.
1984	1411.	0.	-230.31	234.915	6431.375	390200.	43411.
1985	1456.	0.	-229.90	236.095	6527.795	394640.	43262.
1986	1365.	0.	-229.80	236.372	6550.390	399080.	43587.
1987	1371.	0.	-229.72	236.618	6570.515	403520.	43925.
1988	1310.	0.	-229.96	235.907	6512.458	407960.	44776.
1989	1193.	0.	-230.55	234.221	6374.733	412400.	46191.
1990	1187.	0.	-231.09	232.669	6247.936	416840.	47585
1991	1300.	0.	-231.15	232.509	6234.896	421280.	48171.
1992	1387.	0.	-230.82	233.457	6312.276	425720.	48085.
1993	1413.	0.	-230.41	234.616	6407.013	430160.	47876.
1994	1469.	0.	-229.84	236.259	6541.230	434600.	47395
1995	1644.	0.	-228.43	240.371	6877.129	439040.	45603
1996	1212.	0.	-229.14	238.298	6707.782	443480.	47171.
1997	1164.	0.	-229.84	236.274	6542.463	447920.	48787
1998	1312.	0.	-229.99	235.822	6505.520	452360.	49522
1999	1321.	0.	-229.93	236.017	6521.425	456800.	49873
2000	1399.	0.	-229.66	236.797	6585.151	461240.	49871.
2001	1392.	0.	-229.47	237.329	6628.580	465680.	50015
2002	1270.	0.	-229.82	236.310	6545.399	470120.	51092
2003	1309.	0.	-229.98	235.853	6508.008	474560.	51841
2004	1317.	0.	-230.08	235.571	6484.960	479000.	52486
2005	1354.	0.	-230.05	235.670	6493.055	483440.	52890
2006	1446.	0.	-229.47	237.347	6630.095	487880.	52296
2007	1475.	0.	-228.98	238.755	6745.083	492320.	51889
2008	1490.	0.	-227.93	241.838	6996.928	496760.	50525
2009	1410.	0.	-227.61	242.791	7074.791	501200.	50420
2010	1583.	0.	-226.53	246.023	7338.816	505640.	49086
2011	1641.	0.	-225.46	249.265	7603.917	510080.	47837

Table 1

WITHOUT CONSERVATION

SALTON SEA OPERATION STUDY UNCONTROLLED

YEAR	FLOWS (1000 AC FT)	PUMP	ELEV.	AREA (1000 AC.)	VOLUME (1000 AC FT)	SALT (1000 TONS)	PPM
1980	1065.	0.	-229.65	236.805	6585.825	372440.	40551.
1981	1186.	0.	-230.28	234.981	6436.827	376880.	41940.
1982	1203.	0.	-230.94	233.093	6282.602	381320.	43427.
1983	1356.	0.	-230.76	233.621	6325.751	385760.	43627.
1984	1411.	0.	-230.31	234.915	6431.379	390200.	43411.
1985	1456.	0.	-229.90	236.095	6527.799	394640.	43262.
1986	1365.	0.	-229.80	236.372	6550.390	399080.	43587.
1987	1371.	0.	-229.72	236.618	6570.515	403520.	43925.
1988	1310.	0.	-229.96	235.907	6512.458	407960.	44776.
1989	1193.	0.	-230.55	234.221	6374.733	412400.	46191.
1990	837.	0.	-232.61	228.384	5897.936	416420.	50256.
1991	950.	0.	-234.11	224.236	5559.076	420440.	53693.
1992	1037.	0.	-235.12	221.156	5333.056	424460.	56387.
1993	1063.	0.	-236.05	216.308	5129.489	428480.	59058.
1994	1119.	0.	-236.64	213.289	5002.744	432500.	61030.
1995	1294.	0.	-236.18	215.666	5102.560	436520.	60421.
1996	862.	0.	-238.03	206.347	4711.259	440540.	65772.
1997	814.	0.	-239.74	198.106	4365.222	444560.	71330.
1998	952.	0.	-240.63	193.981	4192.030	448580.	74754.
1999	971.	0.	-241.17	191.507	4088.131	452600.	77197.
2000	1049.	0.	-241.34	190.700	4054.252	456620.	78459.
2001	1042.	0.	-241.57	189.688	4011.780	460640.	79901.
2002	920.	0.	-242.41	185.905	3852.933	464660.	83683.
2003	959.	0.	-242.92	183.652	3758.323	468680.	86358.
2004	967.	0.	-243.20	182.012	3689.469	472700.	88578
2005	1004.	0.	-243.45	181.378	3662.820	476720.	89893
2006	1096.	0.	-242.91	183.731	3761.656	480740.	88369
2007	1125.	0.	-242.47	185.670	3843.047	484760.	87291
2008	1140.	0.	-241.48	190.089	4028.609	488780.	84158
2009	1060.	0.	-241.38	190.542	4047.626	492800.	84434
2010	1233.	0.	-240.32	195.406	4251.834	496820.	81230
2011	1291.	0.	-239.30	200.218	4453.887	500840.	78342

Table 2

WITH CONSERVATION

5-15

United States Department of the Interior

BUREAU OF RECLAMATION
LOWER COLORADO REGIONAL OFFICE
P.O. BOX 427
BOULDER CITY, NEVADA 89005

IN REPLY REFER TO: LC-762
120.1

APR 15 1982

Memorandum

To: Members of the Environmental Resources Subteam

From: Team Leader, IID, Water Conservation Opportunities Study

Subject: Environmental Resources Subteam Meeting

During the team meeting held August 8, 1980, your agency expressed interest in participating on the Environmental Resources Subteam. The first Environmental Resources Subteam meeting is scheduled for April 27, 1982 at 10 a.m. in the conference room of the Imperial County Airport. The purpose of the meeting is to discuss the enclosed preliminary draft of the Environmental Chapter for the Water Conservation Opportunities, Imperial Irrigation District appraisal report. Please review the document in regard to its adequacy of addressing the significant environmental resources and issues associated with this project. The format of the chapters will probably be changed in the final draft.

We would appreciate it if you would either send your comments to our office by April 30 or bring them along to the meeting.

David P. Overvold

Enclosure

cc Wilson w/encl
Welch

IV. SETTING

B. Natural Environment

4. Ecology.

a. Aquatic Communities.

(1) Canals, Laterals, Reservoirs, Surface Drains, and Associated Wetlands. The Imperial Valley is laced with over 1,650 miles of irrigation canals and laterals that receive about 3 million acre-feet of Colorado River water annually. The canals vary in size and support a significant amount of aquatic habitat. Although sizable gamefish populations exist, they have been generally underutilized.

Canal seepage supports marsh and riparian communities which usually represent the only such habitat found for miles in this desert community. These areas support a wide variety of flora and fauna.

(a) Water Quality. Irrigation water is by far the highest quality water found in the area. Salinity ranges from 800 to 900 mg/L. Nutrients are also low with nitrate levels ranging from 0.89 to 1.37 mg/L and orthophosphate at 0.01 to 0.078 mg/L (Engineering-Science 1980). The USGS conducted a 4-year water analysis program on the All-American Canal and found that toxic materials (i.e., pesticides, herbicides, metal ions) were rarely found.

The quality of water found in drains is substantially poorer than canal water due to the leaching of salts, increased turbidity, and pesticide and herbicide carryover. Water quality parameters vary considerably due to local agricultural and irrigation practices.

(b) Vegetation.

(1) algae. Investigations on the Coachella Canal (Baker, 1981) identified 18 phytoplankton genera. Diatoms dominate the phytoplankton communities with 12 genera.

Filamentous blue-greens (*Lyngbya* and *Oscillatoria*) are also present where substrates and velocities permit. Their densities fluctuate directly with irrigation demands and changing canal velocities (Engineering-Science, 1980).

(2) macrophytes. Emergent and submergent species are both represented in the system. Emergents are predominantly cattails (*Typha*) and reeds (*Phragmites*). A bank stabilization program of Imperial Irrigation District included the planting of these species along canal shorelines to prevent bank erosion.

Submergent vegetation in the larger canals is less common compared to smaller laterals where plant growth sometimes restricts water movement and becomes a problem. Pondweed (Potamogeton) and Eurasian-milfoil (Myriophyllum) are the dominant submergents.

West of the New River the submerged macrophyte Hydrilla verticillate has been reported since 1977. Hydrilla is an extremely prolific aquatic which attains densities that prevent or restrict canal flow and water deliveries. Intensive investigations regarding possible control measures are now being studied. California Fish and Game Department has closed the infested area to fishing and other recreational activities in order to prevent further spread of the plant.

(c) Invertebrates. Zooplankton communities appear to be extremely limited due to the canals' continual velocities and lack of habitat diversity. Protozoans (Centropyxis aculeata), rotifers (Euchlanis sp.) and the developmental stages of cyclopoid and harpacticoid copepods are the only organisms reported (Baker, 1981) in the Coachella. No information is available regarding other canals or drains.

Benthic communities, especially in the Coachella Canal, have been studied to some degree. Marsh and Stinemetz (1980) identified 17 distinct taxa of macroinvertebrates in the Coachella Canal. Baker (1981) reported similar findings and their combined species list is given on Table __.

Filter feeders (C. manilensis) and chironomids) and sediment ingesters (oligochaeta) were the predominant species.

Areas that supported emergent and submergent vegetation also supported higher invertebrate numbers. Periphyton, however, was found to be very productive on concrete structures (i.e., checkdrops and siphons).

(d) Fish. Fish found in the canal system of Imperial Valley are representative of Lower Colorado River fishes (Table __). Seventeen species have been identified in the All-American and 18 in the Coachella. Various sampling efforts (Engineering-Science, 1980, St. Amont, et. al., 1974) have been made on the larger canals but none as thorough as Minckley (1981). Minckley sampled three canal sections with different structural features. Total biomass of fishes was consistently high in each sample section but varied substantially. Estimates of standing crop for these sample sections were: 910 lbs/acre, 437 lbs/acre and 5,300 lbs/acre. Species composition for his sample is given on Table __.

No information is available concerning the fish community found in seeps and marshes which parallel the canal system. Drain systems in Imperial Valley were sampled by Herrgesell (1975) and found to contain six fish species which included carp, golden shiner,

Table ___
IDENTIFIED COACHELLA CANAL MACROINVERTEBRATES
OCTOBER[1] and NOVEMBER[2] 1980
Water Conservation Opportunities
Imperial Irrigation District, California

Insecta

Ephemeroptera

- Baetidae (genus?)
- *Bactis* sp.

Odonata

- *Hetaerina americana*
- *Hyponeura lugens*
- Anisoptera (genus?)

Trichoptera

- *Smicridea utico*
- *Nectopsyche* sp.

Lepidoptera

- *Parargyractis confusalis*

Diptera

- *Chrysops* sp.
- *Chironomus* sp.
- *Chricoptopus* spp.
- *Cryptochironomus* sp.
- *Thienemanniella* sp.
- Chironomidae (genus?)

Non Insecta

- Turbellaria
- Nematoda
- Oligochaeta (two taxa)
- Ostracoda
- Hydracarina
    - *Lebertia* sp.
- Nematopmorpha
    - *Paragordius* sp.
- Hydracarina
    - *Lebertia* sp.
- Physidae
- Pelecypoda
    - *Corbicula manilenses*
- Amphipoda
    - *Hyallella aztica*
- Decapoda
    - *Procambarus clarki*

1/ Marsh and Stinemetz 1980.
2/ Baker and Paulson 1981.

Table __

ABSOLUTE (KG) AND RELATIVE WEIGHTS (%) OF FISHES COLLECTED FROM THE COACHELLA CANAL, CALIFORNIA, NOVEMBER 1980

Species	Sample Section A Total	(910 lbs/acre) %
Threadfin shad	132.11	16.1
Carp	477.60	58.3
Goldfish	0.04	Tr.1/
Red Shiner	0.17	Tr.
Yellow bullhead	0.31	Tr.
Channel catfish	190.63	23.3
Flathead catfish	3.45	0.4
Striped bass	0.13	Tr.
Bluegill	4.45	0.5
Warmouth	0.24	Tr.
Black crappie	0.08	Tr.
Largemouth bass	9.19	1.1
Zill's tilapia	0.26	Tr.
Total	818.66	99.7
	Sample Section B	(437 lbs/acre)
Thread shad	0.12	Tr.
Carp	102.07	15.6
Red shiner	0.55	0.1
Channel catfish	521.89	79.9
Flathead catfish	1.78	0.3
Bluegill		
Redear sunfish	16.74	2.6
Warmouth		
Largemouth bass	9.78	1.5
Total	652.93	100.0
	Sample Section C	(5,300 lbs/acre)
Threadfin shad	0.05	Tr.
Carp	190.04	31.3
Red shiner	0.02	Tr.
Channel catfish	259.26	42.7
Flathead catfish	151.72	25.0
Bluegill	2.48	0.4
Largemouth bass	4.06	0.7
Total	607.63	100.1

1/ Tr. = less than 0.05%.

redshiner, black bullhead, yellow bullhead, and mosquito fish. Although game fish (i.e., sunfish, bass, and catfish) were not found, they do represent fishes sampled in Palo Verde and Coachella Irrigation Drains. Their limited occurrence should not be ruled out.

(2) Alamo and New Rivers. These rivers have similar water qualities and aquatic habitats. Both rivers originate in the Mexicali Valley, Mexico and flow northward through the Imperial Valley into the Salton Sea. Although the rivers originate in Mexico, the major water source comes from irrigation drainage in Imperial Valley, making the rivers almost totally dependent upon Colorado River water. In most years the rivers constitute the majority of constant inflow to the Salton Sea.

(a) Water Quality. The water quality of both rivers is considered poor. Of the two, the Alamo is slightly better, because sewage effluent from Mexicali makes New River water extremely high in coliform bacterial counts (62,000 to 23,000 MPN/100 ml.). Salinity fluctuates from 2,000 to 6,000 mg/L depending upon season and diversion rates.

Both rivers are extremely turbid and nitrogen and phosphorus levels are also quite high compared to other bodies of water in Imperial County. Nitrate and orthophosphate levels for the Alamo River, January 1979 averaged 50 mg/L and .201 mg/L, respectively, compared to 2.4 mg/L and .047 mg/L levels taken from Salton Sea waters near Wister (Engineering-Science, 1980).

The U.S. Geological Survey (USGS) water quality analyses of Alamo River water frequently detected a variety of pesticides, herbicides and other toxic substances. Usually concentrations are less than 0.2 microgram per liter although some levels reach several micrograms per liter which can cause invertebrate and fish mortality.

(b) Vegetation.

(1) algae. The algae communities of either river system are extremely limited due to high turbidity, velocities, and possible periodic influxes of herbicides.

The green algae (*Cladophora*) can be found in limited quantities in both rivers along witn bluegreen algae (Oscillatoria, *Lyngbya*, and *Anabaena*), and fresh water diatoms (*Navicula*, *Nitzschia*, *Synedra*) (Engineering-Science, 1980).

(2) macrophytes. Submergent vegetation has not been reported from either river system although it may occur in extremely small quantities. If present, species would probably include various pondweed (*Potamogetom* sp.) and eurasian milfoil (*Myriophyllum* sp). Emergent vegetation is usually restricted to the river banks and include dense stands of tules (*Scripus* sp.), cattails (*Typha* sp.) and Carizo cane (*Phragmites communis*).

(c) Invertebrates. Invertebrate data are limited for both river systems. Data that do exist indicate that rotifers appear to be the dominant zooplankton with some amphipods and cladocera found. Benthic invertebrate fauna is apparently restricted to the shoreline along emergent vegetation and debris. Chironomid larvae is apparently the most abundant insect larvae. Other types of larvae included mayflies (Ephemeralla, Heptagenia), dytiscid beetles (?) and odonate nymphs (Archilestes sp.) Asian clams (Corbicula sp.) and crayfish (Procambarus sp.) are also present (Engineering-Science, 1980).

(d) Fish. The fish community of the New and Alamo Rivers consists of nonnative fishes (Table __) which reflects the totally modified fishery compared to what might have existed historically. A fish sampling effort by Engineering-Science (1980) using various netting procedures yielded five species of fish. Table __ shows that Carp (93 percent) dominated the total catch.

Table __
FISH SPECIES COLLECTED FROM THE ALAMO RIVER (ENGINEERING-SCIENCES, 1980)
WATER CONSERVATION OPPORTUNITIES
IMPERIAL IRRIGATION DISTRICT, CALIFORNIA

Species	Total No.	Percent
Carp	249	92.9
Goldfish	8	3.0
Channel Catfish	7	2.6
Yellow Bullhead	3	1.1
Tilapia (mossambica)	1	0.4
Total	268	100

Fish migration in the Alamo River is restricted by a large scale network of erosion control structures. Fish communities are maintained by natural reproduction and a possibility of recruitment by fish moving downstream. Fish migration from the Salton Sea into the river systems undoubtedly occurs for short distances. These interface areas which have moderate salinity levels may be important reproductive habitat for Salton Sea fishes and may become increasingly important as salinity rates increase.

(3) Salton Sea. The Salton Sea represents the largest lake found in California and has a surface area of 360 square miles. The Sea was formed in the lowest part of a closed basin, 278 feet below sea level, by an accidental diversion of Colorado River floodflows in 1905-1907. Since then it has been maintained by flows of natural runoff and manmade diversions into the basin. The Sea's popularity as a recreational area for southern California is ever increasing. The area supports fishing, boating, swimming, camping, and picnicking.

Table ___
COACHELLA CANAL SPECIES COMPOSITION
(MODIFIED FROM MINCKLEY, 1980)
Water Conservation Opportunities
Imperial Irrigation District, California

Species	Sample Number	Sample Percent
Threadfin Shad	2,927	29.3
Carp	233	2.3
Goldfish	1	tr.
Red Shiner	564	5.6
Channel catfish	4,674	46.7
Yellow bullhead	2	tr.
Flathead catfish	94	9.4
Striped bass	1	tr.
Bluegill	301	3.0
Redear sunfish	79	0.8
Warmouth	4	tr.
Black crappie	3	tr.
Largemouth bass	216	2.2
Zill's tilapia	6	0.1
Mosquito fish	obs.	--
Sailfin molly	obs	--
Total	9,105	

obs. - observed, not collected.
tr. less than 0.05 percent.

(a) Water Quality. According to a 1970 report (FWQA 1970) the Sea's water quality for recreational uses is generally good and is unlikely to present any significant health or safety problems for recreationists in the future. The only areas that are considered bacteriologically unsafe for water contact recreation are around the confluences of the New and Alamo Rivers. Water quality, especially salinity, is a major issue in the survival of aquatic organisms. Since the Sea is in a closed basin, all minerals that enter the basin remain while the process of evaporation continues. Average annual salt inflows amount to 5 million tons which increases the Sea's salinity. Currently salinity fluctuates between 37,000 mg/L and 38,000 mg/L. Projected salinity values calibrated by historic increases are given on Table __.

In a closed basin, pesticide and herbicide concentrations would be expected to accumulate but toxic levels are not significant in the Sea. In 1972 water samples were analyzed by the U.S. Geological Survey Laboratory and found chlorinated hydrocarbon levels below the standards identified in the "Water Quality Control Plan for Ocean Water of California."

(b) Vegetation. Twenty-two species of planktonic algae comprised of green algae, euglenoid algae, dinoflagellates and diatoms have been identified (USDI, RAC 1974). Diatoms and dinoflagellates make up the majority of abundant species. The four major species, Nitzchia longissima, Cyclatella caspia, Glenodinium sp., and Exuviells compressa, make up the bulk of aquatic vegetation produced in the Sea (Walker, 1961).

The high nutrient inflow from the New and Alamo Rivers contributes to an extensive phytoplankton community which is typical of eutrophic systems. Algal blooms periodically occur that result in fish kills, odors, and other anoxic conditions. These conditions have occurred since 1954 and it has been concluded that the plankton blooms situation will not worsen (USDI, RAC, 1974).

(c) Invertebrates. The invertebrate diversity of the Sea, along with other aquatic organisms, is extremely limited by the variety of habitats and the chemical composition of the water. Extensive introductions of various marine invertebrate species were made between 1930 to 1957 with no success.

Six phyla (Protozoa, Rotifera, Bryozoa, Nematoda, Annelida and Arthropoda) of invertebrates are found in the Sea. Zooplankton species include several protozoan species, the rotifer, Brachionus plicatilis and the copepod, Cyclops dimorphus. Benthic organisms recorded include barnacles, Balanus amphitrite, various ostracods, nematodes, bryozoans and the annelid, Neanthes succinea (Linsley and Carpelan, 1961).

Copepods, rotofers and the annilid or "pile worm" are important forage items for fish.

(d) Fish. The fish community of the Sea since its creation in 1905-1907 has been continuously changing. The original population formed by the inundation was typical of the Colorado River. Because the system is in a closed basin, salinity steadily rose, eliminating fishes less tolerant of higher salinity. Today the desert pupfish (*Cyprinodon macularius*) is the only native fish found in the Sea. It is questionable whether this species came from isolated desert spring stocks located in the area (i.e., San Felipe Creek) or from the Colorado River.

The California Department of Fish and Game conducted extensive marine introductions into the Sea from 1929 to 1956 but had limited success. Today the fish community is represented by 11 species which include:

Threadfin Shad	*Dorosoma petenense*
Desert Pupfish	*Cyprinodon macularis*
Mosquito fish	*Gambusia affinis*
Sargo	*Anisotrenus davidsoni*
White Croaker	*Bairdiella icistius*
Orangemouth Corvina	*Cynoscion xanthulus*
Shortfin Corvina	*Cynoscion parvipinnis*
Long-jawed Mudsucker	*Gillichthys mirabilis*
Sailfin Molly	*Poecilia latipinna*
"Tilapia"	*Sarotherodon mossambica*
"Tilapia"	*Sarotherodon aurea*

Occasionally freshwater fishes are reported near the southern end of the Sea. Carp, sunfish, and catfish can invade the Sea from the canals and the New and Alamo Rivers for short periods of time; however, salinity stress will ultimately lead to mortality unless the fish return upstream.

Orangemouth corvina, White croaker and Sargo make up an extremely important and valuable fishery (Black, 1974). However salinity levels exceeding 40,000 mg/L are expected to seriously impact natural reproduction and survival of these fishes (Hanson, 1970; Lasber, et al., 1972; Brocksen and Cole, 1972).

b. Terrestrial Communities. This section will only cover those terrestrial communities that could possibly be affected by the project.

(1) Agricultural. Land use in Imperial Valley is extensively agricultural. Major crops produced include various table foods, grains, and other domesticated crops. Livestock and dairy products are also produced.

(a) Vegetation. Ruderal or weedy vegetation occurs along disturbed areas in the agricultural community such as roadsides, field borders, canal banks, and railroad rights-of-ways. Vegetation is generally restricted to "weedy" species such as pigweed, cheeseweed, shepherd's purse, saltbush, salt cedar, and various thistles and grasses. Growth is often controlled by mowing, herbicides, or burning. These weedy areas provide the only semi-permanent habitat remaining in agricultural areas.

(b) Wildlife. Bird species use agricultural fields primarily as a food source. It is reported that 203 species of birds have been sighted in this habitat type. Common species include English sparrows, pigeons, brown-headed cowbirds, starlings, white-winged and mourning doves. During the fall and winter, waterfowl feed and return to nearby refuges or continue their migration. After feeding local populations return to protective shelter or roost sites located outside the agricultural area.

Mammals in the agricultural community are primarily restricted to ruderal areas. Border habitat supports roundtailed ground squirrel, house mice, deer mice, and the western harvest mice. Larger, mobile mammals include foxes, coyotes, badgers, and skunks.

Reptiles and amphibians are also restricted to border areas. Species include various lizards and snakes.

(2) Canal Riparian.

(a) Vegetation. Riparian growth is generally restricted to a 3- to 15-foot wide corridor along canal shorelines. Common reed and saltgrass are usually found in dense stands near the waters edge and as the canal banks slope increased toward the top of the levee, riparian vegetation decreases sharply.

Levee vegetation found on the outer slopes and berms is often sparse and weedy, typical of plant species found in the adjacent plant communities.

Along some canals, riparian vegetation such as baccharis, arrowweed, tamarisk, and occasionally stands of cottonwood is found adjacent to the canal and is supported by seepage water.

(b) Wildlife. Wildlife diversity of the canal community is heavily influenced by the type of vegetative community it transverses. Literature review and field investigations (Engineering-Science, 1980) indicate 20 species of mammals, and 17 species of reptiles and amphibians and 88 species of birds associated with this type of community.

- Reptiles and Amphibians. Seventeen species of amphibians and reptiles are reported in the canal riparian community. However, field investigations by Engineering Science (1980) found only three species common within this community, the bullfrog (*Rana catesbeiana*), woodhouse toad (Bufo woodhousei), and spiny softshell turtle (*Trionyx spiniferus*).

- Mammals. Muskrats are the most conspicuous mammals. The round-tailed ground squirrel, kangaroo rat, southern pocket gopher, and deer mouse are also commonly found in short vegetation along canal banks.

- Birds. Bird use of this community varies with the type and amount of vegetation present and the adjacent land use. Some common species include the black phoebe, western kingbird, red-winged swallow. Waterfowl find food and cover in the canals and associated vegetation. The burrowing owl is common and nests along steep canal banks where vegetation is sparse.

(3) Alamo and New River Riparian.

(a) Vegetation. The river riparian community of the New and Alamo Rivers represents the majority of available riparian habitat in Imperial Valley. Riparian vegetation is restricted in most areas to a thin corridor (50 to 100 feet) because of extensively developed farmlands. Vegetation in many areas forms shrubby, extremely dense thickets of salt cedar, common reed, wing scale, and giant reed. Willow and cottonwood trees are found occasionally. Other common plant species encountered are arrowweed, seepwillow, cattail, iodine bush, quailbush and various agricultural oriented weeds. Tamarisk is the most dominant riparian species.

Species diversity and density are restricted by the availability of surface or subsurface water. Phreatophyte species are dependent upon a permanent water source. Some species such as tamarisk and mesquite are deep-rooted and more adaptable than shallow-rooted species like seepwillow and arrowweed.

(b) Wildlife. The importance of riparian habitat to wildlife is well documented. The riparian corridors of the New and Alamo Rivers however, are considered to be of low to moderate quality for wildlife due to several factors. The community is of limited areal extent, being constricted to a narrow band by adjoining agricultural fields. Dense thickets of salt cedar occupy a large percentage of the riparian corridor. Such homogeneous stands support fewer numbers and lower diversity of species than native heterogenous riparian communities. The limited value of salt cedar to many species, the lack of structural diversity, lack of microhabitat variation, and limited areal extent of the riparian corridor all contribute to a low quality assessment.

Despite the rather low quality of the riparian habitat, this community contains important wildlife values. Bird abundance and diversity remains higher than in surrounding desert and agricultural areas and is a major nesting area of mourning doves. The riparian corridor serves as an extremely important migration avenue. The rip ian areas also play an important role for the area's waterfowl populations, providing cover, roosting, and nesting sites for many waterfowl species which feed in the adjacent agricultural areas.

The New and Alamo River riparian community apparently supports few mammal species (Engineering-Science, 1980). The deer mouse, cotton rat, and insectivor bat make up the majority of small mammals present. Other species which occur but apparently are not common include the muskrat, raccoon, grey fox, and coyote.

(c) Amphibians and Reptiles. The spiny soft-shell turtle (*Trionyx spiniferus*) has been reported in the Alamo River and probably exists in the New River also. Although not reported, bullfrogs, toads, and other species may be present.

(4) Wetland. Basically there are three categories of wetlands in Imperial Valley: (1) deltaic marshes of the Salton Sea, (2) marshes of riverine and open water areas, and (3) marshes associated with canal seepage.

Deltaic wetlands were formed at the confluence of the New River, Alamo River, Salt Creek, and Jim Folger Creek with the Salton Sea. With increased inflow to the Sea, water elevations have increased about 4 feet in 7 years resulting in the inundation and subsequent loss of wetland habitat. Existing wetlands are still threatened by inundation of the Sea.

Riverine marshes and lakes are concentrated along the Alamo River, Finney Lake, Ramer Lake, and the Salton Sea National Wildlife Refuge are the major wetlands. Numerous private waterfowl clubs also manage wetlands for waterfowl.

Wetlands along the Coachella, East Highline, and All-American Canals are maintained by canal seeps. Seepage wetlands associated with the major irrigation canals rarely exceed 5 acres in size but a few are much larger. The turnout area of the East Highline Canal from the All-American Canal supports the largest and best developed seep wetland in the area.

(a) Vegetation. The vegetative species are basically the same for the different wetlands except that species diversities and compositions may vary depending upon local conditions. Cattails and common reed are the predominant species in most areas. Brushy plants such as seepwillow, salt cedar, arrowweed and pampas grass may be found in "drier areas." In general plant diversity in wetlands is quite low (Engineering- Science, 1980).

(b) Wildlife. Wetlands provide probably the most important wildlife habitat in terms of densities and species diversity in the area. This is especially true for birds. Probably the most attractive habitats are those associated with the Salton Sea National Wildlife Refuge, the Imperial Wildlife Area, and one seep area found on the All-American Canal. At least 170 species of birds, 27 species of mammals, and 5 species of reptiles are associated with this community type (Engineering-Science, 1980).

Mammal trapping efforts by Engineering-Science (1980) showed this habitat supported higher mammal densities than any other habitat type sampled. The cotton rat and brush mouse were the most abundant although other species included the western harvest mouse, house mouse, and white-throated woodrat. The desert cottontail, raccoon, and coyote were also present.

As with small mammals, bird densities were also very high. Field studies conducted by Engineering-Science (1980) at Alamo River, Imperial Wildlife Area, and All-American Canal Wetlands revealed breeding bird densities averaging an estimated 85, 312, and 737 pairs/100 acres, respectively. The high density for the All-American Canal study area was influenced by a colony of yellowhead black birds.

Bullfrogs and leapord frogs are the most common amphibians in the wetland community. Reptiles are generally absent or occur in low numbers, the western whiptail being the most common reptile.

VIII. FORMULATION AND EVALUATION OF ALTERNATIVE PLANS

C. Plan Evaluation

6. Environmental Analysis. The major environmental impacts of a water conservation project would be associated with reducing flow to, and increasing the salinity of the Salton Sea. It is speculated that conservation measures could reduce inflows by 350,000 acre-feet per year or roughly 25 percent of the annual inflow. If this project is activated,it will greatly accelerate the increase of the Sea's salinity.

The following section will discuss the major impacts of each of the water conservation measures discussed in preceding sections and the impacts expected to occur in the Salton Sea area.

1. Canal Lining. Currently canal lining appears to be one of the most viable conservation measures available. Figure __ rates the desirability of lining certain canal areas based on cost per acre-foot of water savings. Lining would increase irrigation delivery efficiency as well as reduce seepage losses and canal maintenance. The associated impacts would be predominantly aquatic although some terrestrial impacts would also occur.

a. Aquatic Impacts. Canal lining could change the densities and diversity of present aquatic flora and fauna. Aquatic vegetation, emergent, submergent and marginal vegetation would be eliminated by lining. This, of course, would reduce the District's problems with aquatic weeds, such as *Hydrilla* but it would also reduce or eliminate aquatic organisms (i.e., macroinvertebrates and small fish species) which are dependent upon that habitat type (Marsh and

Stinemetz, 1980). Changes in the invertebrate community could affect the canal fishery, impacting those fish which are dependent upon invertebrates and bank cover. It is speculated (Minckley, 1981) that sunfish populations (including largemouth bass) would decline.

Lined canals however, may enhance periphyton growth (Marsh and Stinemetz, 1980) which may enhance food production for some fishes such as channel catfish. These predictions are highly speculative and additional research is needed to make accurate predictions.

b. Terrestrial Impacts. Construction of lined canals (filled) would be located adjacent to existing canals. Old unlined canals could be reclaimed for agriculture This would minimize land acquisition which would generally be restricted to agricultural farmland. Impacts to terrestrial wildlife (i.e., small mammals, birds, reptiles) from construction would be minimal.

The elimination or reduction of canal seepage would affect adjacent wetland communities which depend upon seepage water. With the elimination of seepage, wetlands would be expected to convert to adjacent vegetative community types as ground waters recede. The elimination of wetlands would result in a loss of valuable habitat for many species especially birds. This represents the only habitat in some areas for nesting and wading birds (including the Yuma clapper rail and blackrails). It may be feasible to mitigate seepage losses and maintain some wetland areas by ground- water pumping. These possibilities would be explored in feasibility level studies.

The elimination of border stream habitat would greatly affect species such as the muskrat, spiny-shell turtle, amphibian species, and wading birds. Lining could also inhibit access of animals which drink from the canal. In some areas this impact may be substantial, especially where desert species populations are artificially maintained (i.e., gamble's quail) by plentiful water supplies. Terrestrial animal escape would become more difficult in lined canals and some mortality would be expected, especially on the outside borders of the Imperial Irrigation District (District).

2. Regulating Reservoirs. The use of regulating reservoirs to store rejected or unused irrigation deliveries is also a very attractive conservation measure. The District is currently using two such systems and has started the construction of a third.

a. Aquatic Impacts. Regulating reservoirs would have little impact on the aquatic flora and fauna of the canal system. Impacts would be generally beneficial rather than detrimental.

Canal regulation could reduce some of the water surface fluctuation experienced in the drainage systems. Within the impoundments, reduced velocities could possibly result in increased zoo and phytoplankton productivity. The reservoirs may provide limited spawning habitat or could be modified to increase the likelihood of natural reproduction of catfish and sunfish species. A multiple use concept of recreation (angling) and irrigation may be feasible.

b. Terrestrial Impacts. Terrestrial impacts would be minimal if reservoirs were located on agricultural land. Small mammals and reptiles found along the border areas would be displaced but would soon colonize the perimeter of the impoundment.

The addition of surface water would be beneficial for waterfowl. The existing two reservoirs are utilized by waterfowl to a great extent and additional reservoirs would provide additional habitat and minirefuges for local and migrating birds.

c. Other Reservoir Concepts. The use and modification of the Finney Ramer Wildlife area are being explored. The alternative(s) would call for the impoundment of some areas of the refuge, which are not currently wetlands, for the storage of irrigation water. Water quality of the existing wetlands would increase and there may be a broad spectra of mitigation and enhancement possibilities for the new "wetland" area. It is believed that such a project could benefit both the District and enhance the refuge's habitat.

3. System Automation, Wastewater Collection and Reuse, and Onfarm Irrigation Scheduling. These projects would have little direct impact on the immediate environment other than reducing drainage and excess tailwater flows. The following section will discuss the impacts expected to occur as a result of reduced drainage flows.

4. Downstream Impacts Due to Water Conservation Measures. It is predicted the conservation measures could reduce the inflow to the Salton Sea by 350,000 acre-feet annually. Its reduction would amount roughly to a 25-percent inflow reduction.

a. Surface Drains and the Alamo and New Rivers. Reduced drain flow would result in poorer water quality in the drainage canals as well as in the New and Alamo Rivers. Salinity levels would increase as conservation measures reduced the diluting effect (volume) of wastewater. As water volumes decreased, pesticide concentrations may increase somewhat. The further deterioration of water quality of these systems could affect flora and fauna less tolerant of these types of pollution.

It is doubtful if any significant change would occur in the river systems. The present aquatic fauna is restricted to a few catfish and rough fish limiting its value as a fishery. Flow reductions, (especially from construction alternatives) would be gradual. Riparian and emergent vegetation communities currently undergo substantial water elevation fluctuations. Lower flow rates may stress these communities but they are expected to reestablish themselves at a lower streambed elevation. However, increased salinity levels may favor more salt tolerant plants (i.e., salt cedar) at the expense of more desirable vegetation (i.e., willows). Some impacts to the fish, bird and small mammal communities would be expected.

The conservation or reduction of 350,000 acre-feet of inflow to the Salton Sea is expected to reduce the Sea's elevation by 15 feet (-245) where it should stabilize. This reduction may make it feasible to reclaim several thousand acres of delta wetlands which have been lost due to Sea inundation. The Salton Sea National Wildlife Refuge alone has lost over 32,000 acres to inundation. If Sea levels were reduced by 15 feet this acreage could be recovered and possibly managed for wildlife use.

b. Salton Sea. Being a closed basin, the Sea's salinity rate has continued to rise since its creation in 1905. Reduced inflows would accelerate the salinity rate and the demise of the aquatic organisms that inhabit it.

Currently the Salton Sea supports a substantial sport fishery. With the gradual salinity increase, biologists have become concerned about the Sea's ability to sustain its fishery.

Lasker, et al., (1972) reported that Salton Sea water of 40,000 mg/L salinity apparently exceeds the upper tolerance limits of bairdilla and sargo to salinity during embryonic and larval development. May (1976) on the other hand found that the distinct ion characteristics of Salton Sea water rather than salinity contributed to fish egg and fry mortality. His results however, generally agreed with Laskers mortality findings and predicted that 45,000 mg/L Salton Sea water would not support hatching, let alone fry development.

There is some debate over the rate of salinity increase for the Salton Sea. Salinity models have been created using both historic salinity data since 1948 (Figure __) and data from the past 8 years (Figure __). These models predict that the Sea will reach 40,000 mg/L in either 1982 (Figure 8) or 1985 (Figure 10) with or without conservation measures. As stated before, this salinity level is predicted to severely restrict natural reproduction at best. A 45,000 mg/L salinity level is expected to occur in either 1989 (Figure 8) or 1990 with the project, or 1996 without it (Figure 10). At this concentration there is little doubt that a self-substaining fishery would be impossible unless a new more salt (or ion) tolerant fish species were found. These predictions are substantiated by another salinity model developed for Southern California Edison Company by UCLA. However, all these models do not take into account biological or chemical factors that change natural salt removal (i.e., salt preciptation). If salt precipitation or 23 other similar salt removal factors increase the salinity rate increase of the sea may be slowed. Additional research is needed regarding possible biological salinity models.

5. Accumulative Impacts by Other Proposed Projects. The Salton Sea is being studied by other agencies for possible energy development projects. Investigations include solar pond and geothermal development and possible natural gas exploration. Salinity models developed for Southern California Edison Company indicate geothermal development would also increase the Sea's salinity. Solar pond

development could be used to partially offset the salinity increases resulting from water conservation and geothermal development. These reductions however, at best, could not maintain the Sea's salinity below 40,000 mg/L. A closer look at these impacts would be necessary as other agency projects progress.

There is considerable opinion that since the death of the Salton Sea fishery appears inevitable, there is no necessity to mitigate if the project only hastens its death by a number of years. Despite the fact that the fishery may die, each additional year the Sea's fishery is saved will provide hundreds of thousands of recreational use days. This could produce millions of dollars in recreation generated revenues for the local economy which would otherwise be lost.

Increased salinity and reduced water evaluations would have impacts on waterfowl and other water-associated birds which use the Sea. Impacts to dabbling ducks such as pintails, wigeon, and teal could be minimal since these birds feed principally in fresh water and agricultural areas. Impacts to diving birds such as ruddy ducks, scaup and eared grebes may be more severe since their feeding dependence may be more directly linked to the Sea. A reduction in the surface area of the Sea may result in overcrowding, increased occurrence of disease, and hunting pressure.

6. Environmental Conditions Without the Project. Undoubtedly, one of the greatest changes which would affect fish and wildlife resources in the study area with or without the project would be a significant increase in the salinity of the Sea. As previously discussed, salinity models predict salinity rates will reach 45,000 mg/L by 1996 which will result in the demise of the Sea's fishery. Other agencies have proposed projects in the study area which would also increase the salinity of the Sea. A brief description of these proposed projects follows:

a. Water Conservation Efforts of Imperial Irrigation District. The District has an ongoing canal lining program. Implementation of the proposed project would simply accelerate the current program. The District has also constructed three regulating reservoirs and has plans for several other sites. Water conservation efficiency of the District will gradually increase in time, thus reducing spillage or drainage flows into the Sea.

b. California State Department of Water Resources. The California State Department of Water Resources indicated in a 1981 report that water losses are occurring in the District and as a result made eight recommendations that could reduce inflows by about 276,000 acre-feet annually. If implemented, these measures would dramatically increase the salinity and decrease the water level of the Sea. Impacts would be similar to those described for the proposed project.

Consequently, the District's current canal lining program or a major water conservation effort, even without the proposed project, would escalate the Sea's salinity rate and result in the demise of the fishery and other associated impacts.

c. Geothermal Development. The development of geothermal energy in the Imperial Valley could also have major impacts on salinity levels in the Sea. Four known geothermal resource areas capable of producing electrical energy have been identified: (1) East Mesa; (2) Heber; (3) Brawley; and (4) Salton Sea. A draft master EIR (WESTEC 1981b) has been prepared by Imperial County for developing the Salton Sea KGRA. The area encompasses approximately 111,500 acres, the majority of which is found under the south end of the Salton Sea. The most probable production scenario calls for the construction of twenty-seven, 50-MW powerplants between 1982 and the year 2010 with a life expectancy of 30 years. If all 27 plants are constructed, about 84,000 acre-feet of water would be needed annually for the cooling of waste heat. The report recommends that this water be obtained from irrigation canals. Additional water would also be needed for ground reinjection.

Other adverse impacts associated with geothermal development at the Sea include the possibility of accidental spillage of extremely saline brines toxic to aquatic life and bird strike hazards resulting from additional electrical transmission lines.

d. Oil and Gas Exploration. Adverse environmental impacts could result from the proposed Bureau of Land Management (BLM) leasing of all public lands in the Sea (145 square miles) for oil and gas exploration and development. Offshore drilling and construction operations could deteriorate water quality. A chronic leak or major oil spill from offshore drilling platforms in a "closed system" like the Sea could have a devastating effect on fish and aquatic birds.

The recognized high degree of seismic activity associated with this area makes it possible that oil spills could occur.

e. Solar Ponds. The proposed construction of a solar pond by the Southern California Edison Company at the Salton Sea could have far-reaching impacts on fish and avian life. A demonstration 5-MW solar pond, similar to one presently operating on the Dead Sea in Israel, should be in full operation by 1985. If proven effective, construction could begin on a 600-MW solar pond.

The construction of a solar pond large enough to produce 600-MW would reduce sport fishing habitat and possibly result in mortality to birds diving into the 190°F highly saline lower layer of the pond.

A positive aspect of solar ponds is that they could be operated in such a way as to stabilize or reduce the salinity of the Sea.

7. Special Status Species. The Salton Sea area and Imperial Valley support several special status or rare species (Table __).

We can speculate that some aspects of the proposed project could possibly impact one or more of these species.

Sensitive plant species in particular may be impacted by canal lining operations. Figure __ shows these communities in relationship to the study area (Engineering-Science, 1980).

Three other species, the desert pupfish, Yuma clapper rail and the black rail, are also found to inhabit the area and could be impacted by the project. Reductions in canal seepage and inflows to the Salton Sea would impact the habitat of these species. The desert pupfish is found in shallow pools and irrigation drains along the shoreline of the Salton Sea. Currently populations appear to be declining due to predation and competition from other fishes (Black, 1980). Reduced drainage flows could possibly further impact these species.

The Yuma clapper rail and black rail inhabit shallow wetlands and are found extensively in the refuge areas. These birds have been observed in small wetland adjacent to canals. It is doubtful that the refuges would be impacted but a reduction of canal seepage by lining projects may reduce wetland habitat found along the canal system. Additional studies will be necessary during the feasibility stage to accurately assess possible impacts to these species.

8. Recommended Studies. If the Water Conservation Opportunities study is authorized to progress to the feasibility level of investigation, a complete environmental assessment would be required to comply with NEPA regulations. Additional information would be needed to accurately assess the impacts of the study. Further research should include:

a. Additional information regarding aquatic fauna (macroinvertebrates and fish) in lined and unlined canals.

b. Salinity models constructed to predict the salinity levels expected in the Alamo and New Rivers.

c. Information on the ecology and, in particular, habitat use and feeding habits of the predominant species of water birds wintering at the Sea.

d. A better understanding of the ecology and habitat of the Desert Pupfish.

e. A biological salinity model using chemical and physical parameters.

Table __

SPECIAL STATUS SPECIES FOUND IN OR NEAR IMPERIAL VALLEY, CALIFORNIA

Water Conservation Opportunities

Imperial Irrigation District, California

Species	Federally Listed	Federally Proposed	State Listed	Possible Impact
Invertebrates				
Andrew's scarab beetle *Pserdocotalpa andrewsi*		X 1/		
Amphibians - None				
Reptiles				
Coachella Valley fringe-toed lizard *Uma inornata*	X			
Birds				
California yellow-billed cuckoo *Coccyzus americanus occidentalis*			X	
Peregrine falcon *Falco peregrinus anatum*	X		X	
California black rail *Laterallus jamaicensis conturniculus*			X	X
California brown pilican *Pelecanus occidentalis californicus*	X		X	
Yuma clapper rail *Rallus longirostris yumanensis*	X		X	X
Bald eagle *Haliaeetus leucocephalus*	X			
California Least Tern *Sterna aibifrons browni*	X		X	
Fish				
Desert pupfish *Cyprinodon macularius*		X	X	X
Mammals - None				

1/ Candidate species-not yet proposed.

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TELEPHONE 714 355 1112

IMPERIAL IRRIGATION DISTRICT

OPERATING HEADQUARTERS • IMPERIAL, CALIFORNIA 92251

August 31, 1983

RE: LC-470/453

Mr. N. W. Plummer
U.S. Bureau of Reclamation
Lower Colorado Regional Office
P.O. Box 427
Boulder City, NV 89005

Dear Mr. Plummer:

Please refer to your letter of July 8, 1983, regarding the cooperative agreement No. 1-07-30-L0135 between the Bureau and District which is scheduled to terminate on September 30, 1983, and which provides for a water management and water conservation demonstration program. We will be submitting the required report within the 3-month time limit as required by the subject agreement. Also, we will consult with your coordinator in Yuma.

I am pleased to advise you that the District wishes to accept your offer to extend the Agreement for another two years. We will be prepared to execute an amendment to the agreement upon your submittal of the document.

We look foreward to continued cooperation with the Bureau on this and other matters.

Very truly yours,

D A Twogood

D. A. TWOGOOD
General Manager

DAT:gmd
CC: J. R. Wilson
D. G. Welch

United States Department of the Interior

BUREAU OF RECLAMATION
LOWER COLORADO REGIONAL OFFICE
P.O. BOX 427
BOULDER CITY, NEVADA 89005

IN REPLY REFER TO: LC-470
453.

JUL 8 1983

Mr. Don A. Twogood
General Manager
Imperial Irrigation District
P.O. Box 937
Imperial, California 92251

Dear Mr. Twogood:

Cooperative Agreement No. 1-07-30-L0135 between the Bureau of Reclamation (Bureau) and the Imperial Irrigation District (District) will terminate on September 30, 1983. This Agreement provided for a Water Management and Conservation Demonstration Program on 10,000 acres using neutron moisture gages to monitor soil moisture depletion, schedule irrigation dates, and determine amount of water to be applied. Under the terms of the Agreement, the Bureau also provided water level recorders to measure applied water and tail water on selected fields. Under the terms of the Agreement (Paragraph 7), the District is to make available "...the data, information, and experience gained..." to the Bureau. Therefore, in order to evaluate the potential effects of the Irrigation Scheduling Demonstration Program on a District-wide basis, it is requested that a report be prepared and sent to this office, Attention: LC-470, within 3 months after the termination of the Agreement. The report should include the following information:

1. A brief history and summary of program activities.

2. District staff and dollar contributions on a calendar year basis (salaries, equipment, office space, etc.).

3. Acreage served on the program including crops, total sites, and number of farms.

4. Schedule of irrigation logistics (describe how scheduling was accomplished, by whom, how often, etc.).

5. Appraisal of imp~~or~~acts and benefits (yields, water use, etc.).

6. Recommendations for improvement of this type of program.

7. Summary of data by crop on a crop-year basis including cropped acres, water applied, surface water spilled, water from tile drains and yields, and irrigation application efficiencies.

This kind of information will enable us to determine what improvements or changes may be useful in continuing to develop our Water Management and Conservation Demonstration Programs, and to document the accomplishments of the Irrigation Scheduling Program in the District. The Water Management and Conservation Coordinator in the Yuma Projects Office will be available to assist you in preparing the above report.

The results have been positive and we believe that it would be beneficial to both of us if the program, under the same terms of the above Agreement, were continued for another 2 years or a period of time mutually agreed upon. The Bureau is willing to prepare an amendment to the Agreement that would extend it beyond September 30, 1983. If you concur, please let us know and we will take the necessary action to extend the Agreement. Any questions you might have should be directed to Mr. Val Carter at (702) 293-8562.

Sincerely yours,

Rory C. Gear

ACTING FOR N. W. Plummer
Regional Director

CC For Action:
Mr. Twogood
For Information:
Mr. Wilson

5-17

WATER SYSTEMS AUTOMATION AND MANAGEMENT, PART 1

Session 3-1

Duane F. Nelson

Introduction

Automatic and remote controls are needed for water storage and conveyance systems to improve service to water users, increase efficiency of operation, and reduce cost of operation.

Recent Bureau of Reclamation water-use studies have shown that an average of only 44 percent of the water delivered to irrigators' fields on Reclamation projects is stored in the root zone for beneficial consumptive use by crops. Seepage from canals and laterals accounts for 20 percent of the total water diverted for irrigation in the United States. These percentages do not represent real losses because much of this water returns to streams or replenishes groundwater aquifers that provide the water source for wells or springs. However, there is a real need for improvement of management and utilization of water in irrigation operations. Factors responsible for inefficient management and utilization of irrigation water are many and often interrelated. Application of modern technology in programs of research and development for automation of water systems will improve the efficiency of project and farm irrigation systems and management of conveyance and distribution systems. More efficient use and better management of irrigation can make more water available for municipal, industrial, and recreational use to help meet today's and future needs.

No absolute rule can be made to include or omit automatic or remote controlling and monitoring devices on specific features of Bureau projects. Planners, designers, and operators together face the tasks of analysis and synthesis to arrive at solutions for each feature and/or project. Comprehensive studies of costs, safety, and reliability along with the service to be provided by each feature and the overall type of operation desired should be assembled prior to final decisions. Listed below are some of the items which should be considered in these studies:

1. Water conservation measures
2. Water rights - downstream requirements
3. Operator attendance
4. Accessibility of water system features
5. Communication channels
6. Degree of control desired
7. Maintenance of automation system

8. Reliability of forecasting
9. Rapidity of inflow and time available for operation
10. Consequences of overtopping storage or conveyance features
11. Reliability of power source
12. Reliability of automatic control equipment
13. Shutdown time for power generating stations or pumping plants
14. Economic comparisons

The water users' need for water is not always predetermined sufficiently in advance to assure expeditious delivery or permit rapid shutoffs. Such uncontrolled situations as unexpected rainfall or the need for protective spray to prevent frost are often not readily accommodated. Control systems which make water more quickly available greatly enhance the margin of profit for water users, and those which accommodate quick shutoffs can improve system efficiency.

Automation of water systems is needed to reduce labor cost to the water user. Simple automatic devices have been used for many years to operate single water control structures. Although these devices are limited in the degree of control they can provide, they are proven labor-saving devices. In the past most such devices have been for control of individual structures. A real need now exists for equipment and concepts which will provide efficient operation of complete conveyance and/or distribution systems. This requires a systems approach to fit the concepts and equipment to the operational needs. The end product will go beyond automation per se and will include operations research techniques to optimize the controls and operations. Further sophistication of automation devices will not only reduce labor costs but help conserve water through better operation of water control structures.

The facilities of a typical water system can be classified generally as storage works, diversion works, conveyance system, and distribution system. The storage works consists usually of one or more storage reservoir, generally having outlet works for regulation of water releases therefrom, and a spillway for protection of the dam. The diversion works may consist of a typical diversion dam with headworks for controlling releases into the conveyance system and with a sluice gate and spillway for stream regulation and protection of the structure. It may also consist only of a headworks or a pumping plant discharging into the conveyance channel. The conveyance system generally is an open channel system with structures for control of flow in the system and for delivery into the distribution system. It may also be a pipe or aqueduct with control and delivery structures. The distribution system is a series of open ditches or pipe laterals with a control structure and a delivery structure to the water user. Often the same control concepts can be applied to the conveyance and distribution systems.

Automation has been applied in varying degrees to all types of water control structures from the storage works through the distribution systems. Each water control structure serves a specific function in a water system. Generally speaking, all of the control structures control either a water surface elevation by regulation of a control gate or pumping plant, or control the quantity of water being discharged through or into a particular structure. The type of automation selected to accomplish a particular control structure function or to operate a total water system depends upon the requirement for and economics of the particular situation. The discussion of the need for automation in the following sections includes descriptions of the functions of various water control structures as they apply to the segments of the total system. The concepts of operation of the control devices and the applications of these devices are discussed later.

Storage Works

Outlet Works

Perhaps more than any other water control structure, outlet works of dams are operated on a scheduled basis. At present, changes for system demands are seldom made automatically at the storage reservoir. Consequently, most outlet works are either manually or remotely operated. Operation of water systems in a manner which automatically meets the demands of the water users will require automatic operation of outlet works. In many systems, remote control of a distant storage dam outlet works can result in a cost savings due to the elimination of the need for a full-time dam tender.

Spillways

In contrast to the routine operating purposes served by other automatic applications, spillway gate automation serves primarily as an emergency protective device. Spillways pass flood inflows in excess of outlet works discharge and available reservoir storage capacities. The use of gated spillways introduces the possibility of overtopping and failure of the dam if the gates are not properly operated during critical flood periods. Concrete dams provide greater safety against failure due to overtopping; therefore, automatic operation of those spillway gates is not usually required. Automatic spillway gate operation is provided on some Reclamation earth dams to insure proper gate operation.

Diversion Works

Diversion Dams and Structures

While diversion dams and canal headworks are often self-contained and isolated, they can be the focal point for demands of the distribution system. The control operation must not only meet downstream demands in the river and diversion demands, but also must dampen hydraulic transients to provide smooth operation of the entire system. Operation can be very complicated and often requires a hierarchy of control features. For example, a minimum downstream release to the river may be required to meet water rights and/or fish and wildlife commitments. Additional available supply may be diverted. Diversion discharge is, of course, limited to diversion demand and system capacity. Excess supply is usually wasted or bypassed downstream. The discharges involved are often defined legally and very stringent measurements, monitoring, and controlling are required. Automatic controls can be designed to not only provide the control functions required at these installations, but also to perform the logic required for hierarchical decisions.

Pumping Plants

Pumping plants are required to raise water from a water supply to an elevation where gravity flow can deliver the water to the user. Pumping plants are usually designed with several pumping units of various sizes so that the discharge from several combinations of units can closely approximate the water demand at any particular time. Water conveyance systems that operate with manually controlled gate structures can satisfactorily be supplied by a pumping plant that has pumping units with manual ON-OFF control. However, when the water conveyance system is operated automatically on a demand basis, the supply pumping plant must also include automatic downstream control. Thus, the degree of pumping plant automation and the number and sizing of pumping units are defined by the degree of automation provided for the downstream water system.

Conveyance and Distribution Systems

Canal Checks

Canal check gates should be automated to improve the operation of a canal, to isolate reaches of a canal in the event of a break, and to eliminate repetitive operator attendance.

To provide full turnout discharge or delivery from a canal, a specific minimum depth of water is required. Automatic controls will sense deviations of water surfaces on the canal and operate adjacent checks upstream or downstream to provide a nearly constant water level. Interference or interplay between canal checks in series may cause hydraulic transients to build up and create undesirable conditions. Optimum operation will result only from proper control of the entire canal system. A control scheme which takes this interplay into account can result in operation almost as efficient as that of a closed pipe system.

Canal breaks can flood the surrounding countryside. Checks can be operated in such an emergency to isolate reaches of a canal so that the entire canal is not drained. To provide the desired checking action, the check gates may be operated manually, remotely, or automatically.

Manual operation requires manual opening and closing of the gate at the canal check. Remote monitoring and control has the advantage of bringing water level and gate position information to a central point. From this control center, man or computer can make decisions to operate the control gates for the entire system.

Pipe Systems

Full-pressure pipe systems provide the best system of automatic control of discharge. For demand systems, water delivery to turnouts, as with household faucets, can vary from no flow to full flow or vice versa automatically with no prior scheduling by the user. Full-pressure pipe systems meet this demand. Because of this inherent capability, a higher state of automation has been achieved for full-pressure pipe systems than for open systems. However, these pipe systems are sometimes prohibitively expensive, thus low-head pipe systems or open channel systems are used. Also, demand systems do not have universal application.

Low-head pipe systems present special control problems due to their tendency to amplify harmonic surges. The cost of such a system is usually between that of a comparable open channel and a full-pressure pipe system. Many miles of low-head pipe have been installed on Reclamation projects. Generally, such systems do not have the rapid response of full-pressure systems and prior scheduling for operation is required. Special needs do exist for the automatic operation of both full-pressure and low-head pipe systems. On Reclamation projects, common control problems include limiting head to economic ranges, limiting discharge, and minimizing surges and air entrainment.

Turnouts

Automation of gravity-flow turnouts is needed to provide uniform deliveries from distribution systems. A changed water surface in a canal or a changed pressure in a pipeline change the rates of flow through turnouts from the canal or pipeline. Turnout flows that increase or decrease unexpectedly are difficult to accommodate and often create costly and time-consuming problems for irrigators using surface irrigation. Automation can eliminate these problems with equipment that adjusts a turnout to maintain uniform delivery in spite of fluctuating water surfaces or pressures.

Operators of manually controlled canals and laterals often find it difficult to maintain uniform water surfaces while making the changes necessary for operation. This difficulty is increased by the occurrence of unexpected storms. The automation of control structures will increase the stability of water surfaces on canals and laterals where such automation is installed. However, different concepts of automation provide different degrees of stability, some of which are not compatible with gravity-flow turnouts. Automation of the turnout structures can eliminate this incompatibility, thereby increasing the overall flexibility of operating concepts. Improved operation resulting from automated turnout structures will not only benefit irrigators by minimizing problems associated with nonuniform delivery, but will also permit the operators of distribution systems to be more accurate in scheduling operations. Accurate scheduling promotes the conservation of water resources by eliminating the need for operation waste.

Wasteways

Wasteways are the traditional safety valves of canal operation. They remove excess water and prevent overtopping the canal. Scheduled excess or operation waste is caused by inability to adjust turnout flows to exactly equal flow into the canal. Unscheduled excess occurs as the result of unscheduled reduction in delivery flows or inflow resulting from storm runoff. Wasteways require automation to assure that either scheduled or unscheduled excess water is removed from the canal without attendance by an operator.

Wasteways have been automated in the past whenever canals are designed to accept storm inflow or where large amounts of unscheduled excess water can be expected from other sources. Future installations should include such provisions. Operational waste should be eliminated or greatly reduced where a high degree of automation is provided for other structures within a system.

Concepts of Operation

General

If a sufficient supply of water exists and the conveyance system is capable of transporting the appropriate flows, then a water system can be operated to meet the needs of the users. Such a demand-type system is not feasible, however, if the supply or the conveyance of water is limited to lesser amounts than required. Where the use of water must be limited because of less than adequate storage or conveyance capacities, a supply-type system is necessary. For instance, a domestic water supply usually operates to meet the demands of the users whenever a faucet is turned on. However, in times of water shortages, water use is limited and water is available only on a rationed or prorated basis. Conversely, in any water system, if water is available in plentiful supply and the conveyances are adequate, the system can be operated to meet the demands. Otherwise, water may be only available to users with the highest priorities or all users may have available only a fraction of their full demand.

The two most common methods of operating a water system utilize either upstream or downstream control. With upstream control the sensor is located upstream from the structure being controlled, and with downstream control the sensor is located downstream from the structure being controlled. Upstream control is associated with a supply-type operation and downstream control is associated with a demand-type operation. Also, open channel systems have predominantly been operated with upstream control while pressure conduit systems have for the most part been operated with downstream control.

Each of the structures described previously can be operated with either of these methods, but upstream control has been the traditional method of operation on open channel systems. Whether upstream or downstream, the method of operation can be independent of the automation incorporated therein. However, downstream control of open channel systems has been achieved largely through the use of automatic devices.

The operation of storage dam outlet works is usually based on meeting the needs of the water users consistent with providing storage reserves. Thus, releases from storage during periods of adequate supply serve to meet the full demands of the users. During periods of limited supply, however, the releases are restricted and a system of priorities or across-the-board reductions is imposed. The flow of water can be traced through the system from source to user and the control structures described previously can be operated to meet the demand on the system or to deliver a restricted supply to the users.

Upstream Control

Equipment that is operated to regulate a water surface immediately upstream from the controlling element provides upstream control, figure 1. When more water is supplied than is required to satisfy deliveries, the excess is passed downstream to the end of the conveyance where it must be wasted or stored. When the supply is less than the demand, deficiencies will first affect deliveries at the lower end of the system. Satisfactory operation depends upon the amount of water supplied to the system. This type of operation is called a supply system. To assure that all deliveries are satisfied, operators of supply systems usually introduce a little excess water into the system, which results in operational waste.

Traditional operation of a water system is complex, requiring numerous visits to control structures for adjustment when changes are

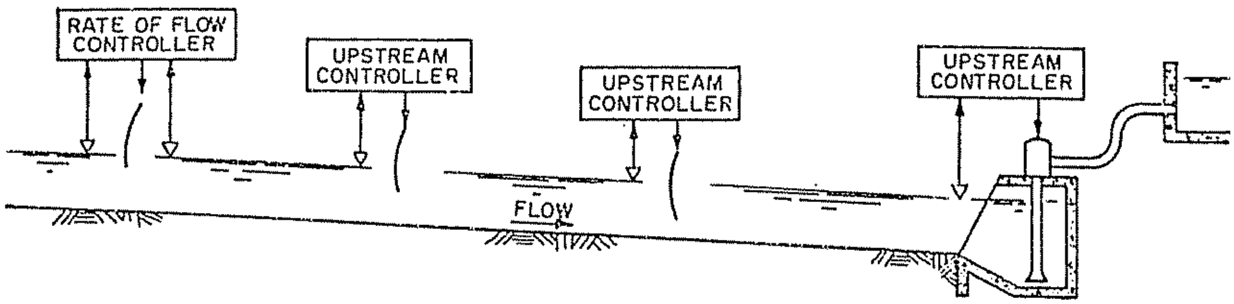


Figure 1.–Upstream control–Supply operation.

made. Water is introduced into the system according to schedules developed from orders placed by users. As the water reaches each control structure in the system, that structure must be adjusted to pass the desired flow. When changes are large, adjustment at individual structures may require several hours. Satisfactory operation requires scheduling sufficiently in advance to allow water to travel from the source to arrive at the point of delivery at the desired time.

Automation of upstream control is most appropriate for structures where inflow cannot be scheduled, such as spillway control gates on dams and wasteway gates that remove storm inflow from a canal. Automation of upstream control is also generally appropriate for structures in conveyances that are operated in the traditional manner. Traditional operation becomes more appropriate as the distance between control structures becomes greater. Other situations which are compatible with traditional operation are long lengths of conveyances with insignificant turnout requirements and conveyances where travel time is not critical, such as a channel which transports water from a large storage source to a large storage sump.

On traditionally operated canals, water surfaces upstream from control structures are normally maintained at a constant elevation for all flow conditions, figure 2. The achievement of uniform flow through each check reach is delayed by the need to either build up or draw down storage within the reach. Extensive systems that require considerable time between the introduction of water into the system and delivery often use regulating reservoirs to speed up response.

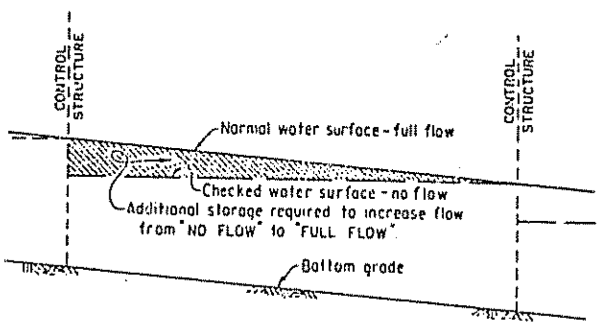


Figure 2.–Traditional concept of canal operation.

Automation can minimize the need for developing schedules for the operation of upstream-controlled structures. In all other respects, the requirements for operating an automated upstream-controlled conveyance are the same as for local manual operation in that:

1. Deliveries may be controlled manually or by some other automatic equipment.

2. Operators must develop schedules for introducing water into the conveyance based on desired delivery rates, desired delivery times, and the time required for water travel to the delivery locations.

These similarities permit the installation of upstream controls on individual structures without requiring automation of the entire conveyance. Rate-of-flow controllers are often utilized at headworks or inlet structures to assure that inflow into the conveyance remains uniform.

Downstream Control

Equipment that is operated to regulate a water surface downstream from the controlling element provides downstream control. The sensor location is selected at a point that provides the best intelligence to relate downstream demands to upstream inflow, to provide stability of control, and to maximize the channel capacity. Generally, this means that the sensor should be at the downstream end of the reach, figure 3.

Where downstream controls are used to maintain uniform flow through a Parshall flume or over a weir, they become rate-of-flow controllers. The control water surface should be located appropriately for measuring depth of flow through the structure. The measuring structure should be installed as near as practical to the controlling element to reduce lag. Commercial rate-of-flow controllers are available to suit nearly all types of commercial measuring devices.

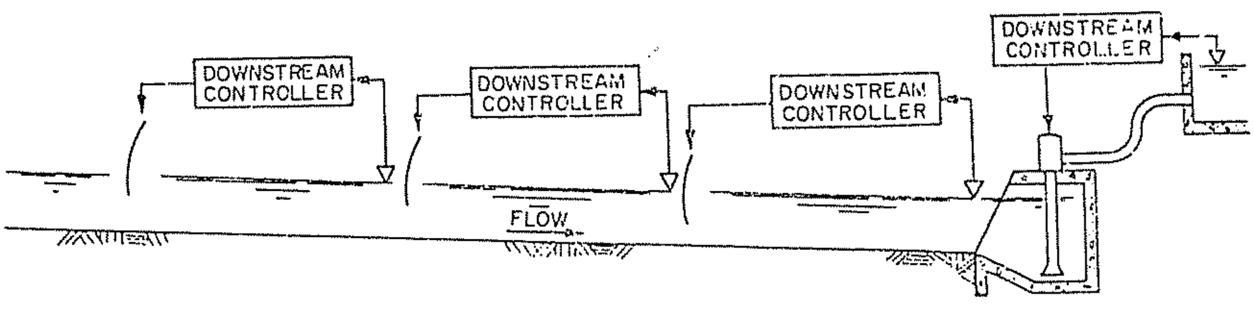


Figure 3 – Downstream control–Demand operation.

Downstream control provides a demand-type operation in which overall operation is controlled by the amount of water being withdrawn from the conveyance. As water is withdrawn, controlling elements are adjusted to introduce water into the system. Operational waste is minimized because the amount of water being supplied to the system at any time is determined by the amount of water being withdrawn.

Downstream control reduces the need for developing schedules for either the operation of individual structures or for introducing water into the system. Except for control of deliveries, no manual input is required as long as sufficient water is available at the inlet or headworks structure. When the supply of water is not sufficient to meet the demand, deficiencies first affect deliveries at the upper end of the system.

Pressure pipe conveyances inherently provide a demand-type operation. However, several factors make demand-type operation more difficult to achieve on open channel systems. Gravity flow with a free water surface is more sluggish and more sensitive to relative variations in head than is flow through pipe under pressure. The time required for a change of flow to move through the system is much greater for an open system than for a pipe system. Water surfaces must be controlled more closely because the physical facilities required to contain wide fluctuations are much more extensive and costly.

Because pressure pipe conveyances inherently provide a demand type of operation, the operators of pipe systems readily recognize the concept of downstream control. Conversely, the concept is difficult for many operators of open channel systems to understand because it is contrary to their traditional method of operation. Upstream controls are not normally intermingled with downstream controls on a conveyance except downstream-controlled rate-of-flow controllers are sometimes used at the headworks of upstream-controlled canals. However, different conveyances within a system may be appropriate to either method of control depending upon operational requirements.

Downstream control is most appropriate for automating structures where deliveries cannot be scheduled, such as in a municipal or industrial water-supply system. The appropriateness of downstream control increases with increasing difficulty in preparing accurate schedules for both introducing water into the conveyance and detailed operation of control structures. An increasing trend toward demand-type operation by irrigators also increases the appropriateness of downstream control for all conveyances that have appreciable delivery requirements.

Controlled Volume Operation

During the formulation of plans for operating the California Aqueduct, the California Department of Water Resources developed a new concept of canal operation. Operation by this method, called controlled volume operation, virtually eliminates the need for regulating reservoirs while increasing operational flexibility. Response time is reduced to the time required to achieve stable flow within a check reach. However, adjustments at control structures must be scheduled and well coordinated.

This new concept was originally called constant volume operation because it appeared that the volume of water within each check reach would be maintained at a nearly uniform value for all flow conditions, figure 4. The concept was modified to accommodate off-peak pumping and renamed controlled volume operation. Except during and while recovering from peak hours, the constant volume concept is used for less than capacity flows.

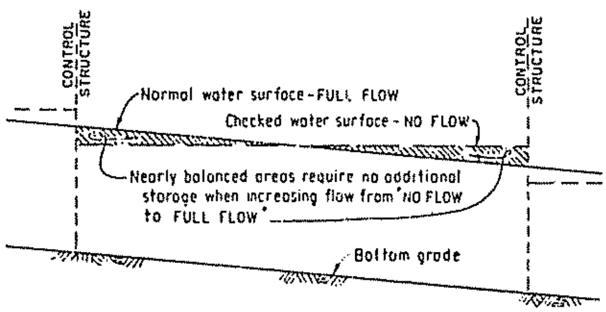


Figure 4.—Constant volume concept of canal operation.

Nearly simultaneous adjustment at all structures makes it possible to adjust canal operation at any time to any desired condition. Remote adjustment of these control structures is needed to provide the coordination required. Detailed schedules of flow requirements at each structure are also needed. Computer-assisted operation is desirable where numerous adjustments must be made simultaneously.

Types of Water Systems Automation

General

The trend in recent years has been toward increased automation of water systems, as described previously. Not only are automatic controls desired for existing installations but automatic operation is also being included for features that are either under construction, in the design stage, or being planned for future construction. This trend increases the importance of understanding both the concepts that are available for operating water systems and the present capabilities of automation to conform to these concepts.

The application of automation to water systems has been in the form of local automatic (feedback) control or remote control. These categories are somewhat overlapping, however, in that remote automatic operation can use feedback control. Nevertheless, the following discussion of feedback control, remote control, and applications serves to describe the current state of the art for automation of water systems.

A completely automatic system requires no input from operators for normal operation. Arrangements of equipment sense physical conditions and make the decisions and adjustments necessary for operation. Municipal water systems often provide highly automated operation in which overall operation of the system is controlled by individual users as they withdraw water from the system. Operators do not enter the decisionmaking process until the conveyance becomes relatively large. Irrigators also desire this type of demand operation.

Because of difficulties in estimating realistic friction factors for conveyances and discharge coefficients for gates, operators of water conveyance systems normally utilize water surfaces at selected locations within the system as indicators of desirable conditions. It thus becomes appropriate for automatic control equipment to utilize water levels to control operation. Flow is normally measured where required for accounting purposes or to assure proper operation of the system.

The automation of industrial processes is highly developed. Knowledge of the characteristic results of different control functions and appropriate application of these functions has developed into a specialty. Where similarities exist, this knowledge and much of the equipment developed for industrial automation have application to Bureau requirements for automatic operation of water conveyance systems. Much of the equipment needed for automatic operation of Reclamation pipe conveyances is available commercially. However, while present technology now makes it possible, there is very little commercial equipment that has been developed specifically for, or can be appropriately applied to, automatic operation of open channel conveyances.

Feedback Control

Basic feedback control systems are designed to return a portion of the output signal to the input of a controller to maintain a prescribed relationship between input and output signals. This feature provides a means to damp out oscillations and produce minimum overshoot for a more stable and responsive control system.

Feedback controls for the automatic operation of water conveyance systems can control either rate of flow or water surfaces. The following discussion is directed primarily toward controllers that control water surfaces, although the principles involved also apply to rate-of-flow controllers. Feedback controls that operate equipment to control water surfaces do not require the difficult field calibrations of gates and valves that are associated with rate-of-flow controllers.

The characteristic manner in which feedback controls perform control functions, or react to deviations of the controlled variable, is called the mode of control. Five common modes of control are two-position control, floating control, proportional control, reset action, and rate action.

Two-position, floating, and proportional controls provide three different control functions, and all three of these modes of control are in common use on Reclamation projects. Equipment installed for each of these types of control varies widely because some of the automation on Reclamation projects has been developed independently by operating personnel. Limitations imposed by mechanical equipment and differing local conditions have also required modification of the control function in many instances.

Reset action is generally used with proportional control to eliminate the offset that is inherent in this mode of control. Rate action may be combined with proportional or proportional plus reset actions to increase the speed of response and reduce overshoot of the controlling element.

A common general mathematical representation of these control functions becomes desirable when feedback control is to be programed into a computer for real-time control or study. Proportional, reset, and rate control can be represented mathematically by the generalized process control algorithm:

$$\text{Output} = \underbrace{K_1\ (e)}_{\text{Proportion}} + \underbrace{K_2 \int_0^N e\ (dt)}_{\text{Reset}} + \underbrace{K_3\ (de/dt)}_{\text{Rate}}$$

where output = position of the controlling element (i.e., gate position)

K_1, K_2, and K_3 = real numbers representing gain factors of proportion, reset, and rate, respectively

e = deviation of the controlled variable (error); i.e., deviation of water surface from target level

de and dt = increments of deviation and time, respectively

N = period of time for reset action

1. Two-position Control

Two-position control is the simplest mode of automatic control. The control function moves the controlling element to one of two extreme positions as determined by the controlled water surface. When these two extreme positions become fully opened or fully closed, the controller becomes an ON-OFF controller, and can be an electrical switch for the operation of pumps, figure 5.

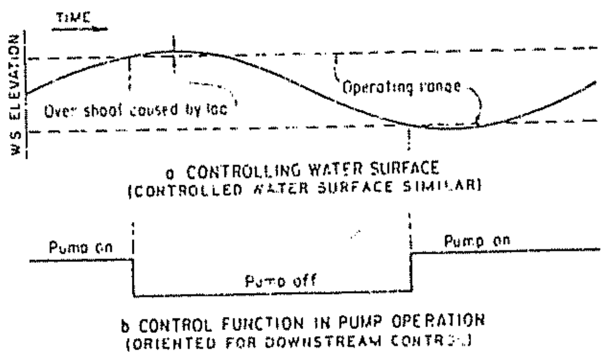


Figure 5 - Two-position control.

Water surfaces controlled by two-position controls will cycle continuously from one side of the operating range to the other.

Excessive cycling can be reduced by increasing storage in the operating range. Corrective action should be slightly larger than the maximum requirement. Two-position controls are most appropriate for installations where storage is large as compared to the rate of corrective action. If storage is large and corrective action occurs at a suitable rate, lag becomes immaterial.

2. Floating Control

In contrast to two-position control which changes the position of the controlling element from one extreme position to the other (ON-OFF), floating control changes the position of the controlling element at a predetermined speed whenever the controlled water surface deviates from its target depth by a predetermined amount. The direction of gate movement is determined by the direction of the deviation. The controlling gate makes no movement as long as the controlled water surface is within the dead band (the desired range of operation). When the controlled water surface is outside the dead band, the controlling gate will continue to move until either the water surface returns to the dead band or the gate reaches a fully opened or fully closed position. The control function and its common modifications are shown in figure 6.

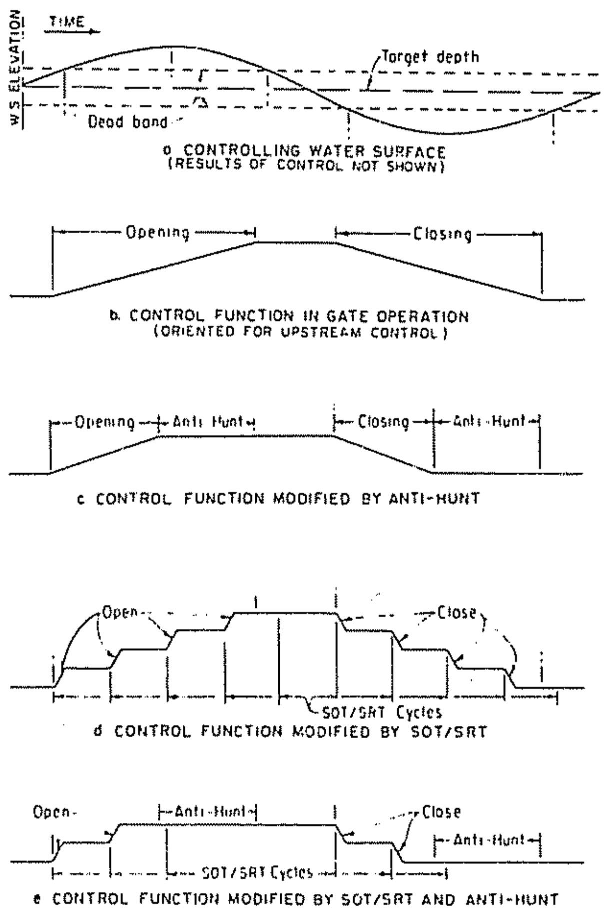


Figure 6.–Floating control

The speed at which the controlling element moves is critical for floating controls. Movement is at a much slower rate than for two-position control because intermediate positioning is desired. Controlled water surfaces have an inherent tendency to cycle, which can be minimized and often limited to the width of the dead band by a proper speed of corrective action. Significant lag in the system, or rapid load changes even though small, will aggravate these cycling tendencies. Floating control is most appropriate for installations with no appreciable lag and where load changes can be counteracted by gradual changes in gate position. Corrective action should be slightly faster than needed to accommodate the most rapid load changes that can occur.

When the controlling gate moves too rapidly it behaves like two-position control with characteristic cycling of the controlled water surface and frequent reversal in direction of gate movement (hunting). Because the mechanization provided on most Reclamation gates is intended to permit manual adjustment as rapidly as practicable, the resulting speed of movement is usually much faster than desired for single-speed floating control. In order to achieve the slower movements required for their installations, most operators have incorporated timers into the control equipment to provide set-operate-time/set-rest-time (SOT/SRT) cycles of operation for gate motors. Adjustability in the timer settings provides flexibility to select the appropriate average speed of gate movement for each structure. A completely stable gate position for uniform flow is seldom achieved by this modification because, as the gate moves a predetermined amount in each cycle, it seldom arrives at the exact position required. However, controls that make two small adjustments or less in an hour are usually considered satisfactory.

A controller that reacts too slowly cannot keep pace with changes and lags behind deviations of the controlled water surface. By the time a lagging controller has made sufficient adjustment of the controlling element to reverse the direction of water surface movement, the adjustment is often larger than needed to maintain uniform flow. Unless the control function is modified, the gate will continue to move while the water surface is returning to the dead band, increasing overshoot in corrective action. Similar lag then creates overshoot in the opposite direction so that long-period cycles develop. Flow conditions can amplify these cycles.

In order to reduce these long-period cycles, some operators have incorporated a friction clutch and additional switches into float-operated equipment to provide an antihunt device. The antihunt device prevents additional gate movement when the controlled water surface is returning to the dead band, even though the water surface is outside the dead band. Use of the antihunt device increases the range of changes that can be accommodated by single-speed floating control.

The major portion of operating time on open channel conveyance systems usually involves steady flow. When changed flow conditions are required, the changes are made as rapidly as possible. In order for a controller to be satisfactory, it not only must provide a stable gate position for steady flow, but also it must be able to change the gate opening rapidly to suit flow changes. Single-speed floating control usually does not have the range of operation needed to suit the extremes of both of these requirements. As a result, most controllers are adjusted to provide gate movements slightly larger than needed for steady flow and antihunt devices are added to reduce the cycling that occurs with flow changes.

Flexibility of some SOT/SRT floating controllers has been increased by superimposing additional control stages, with wider dead bands and faster gate movement, upon a single-speed floating controller.

Figure 7 shows some of the control functions attainable by combining two stages of floating control. The results of mathematical model studies show that one additional stage greatly increases the capability of a controller. Two- or three-stage floating controls may possibly eliminate the need for an antihunt device on installations appropriate for floating control.

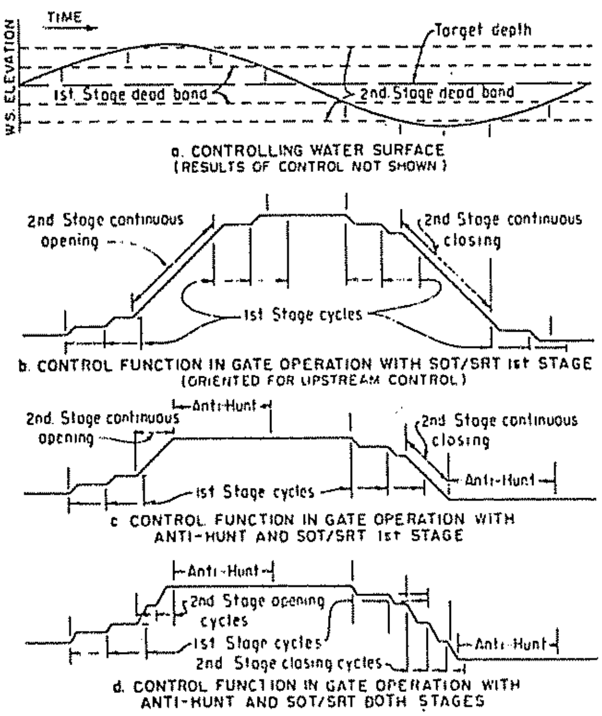


Figure 7.–Two-stage floating control

Flexibility has also been provided for some floating controllers to accommodate rapidly changing water surfaces by the addition of a function that increases the width of the dead band each time the gate moves, figure 8. Increasing the dead band width provides a variable rest time and cycle time so that these controllers become set-operate-time/variable-rest-time (SOT/VRT) controllers. The variable rest time inherently provides antihunt action with all its associated advantages and disadvantages.

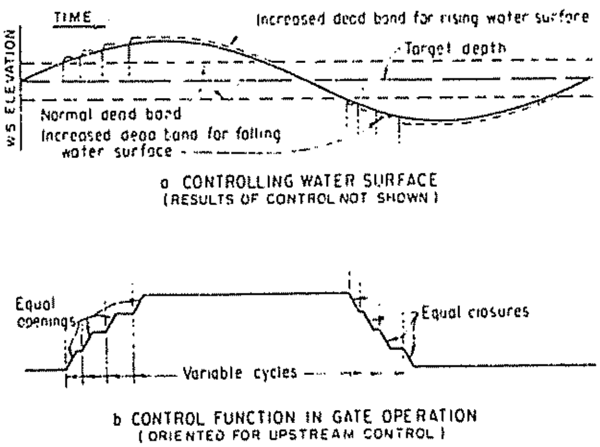


Figure 8.-SOT/VRT floating control.

3. Proportional Control

With proportional control the position of the controlling element has a fixed relationship to the controlled variable. A controlling gate has a position for each water surface elevation that is defined by multiplying deviation of the water surface by a gain factor. The elevation of the controlled water surface varies from one edge of the proportional band for no flow to the other edge of the band for full flow, figure 9.

Because the controlled water surface must be expected to vary throughout the proportional band, proportional control is not appropriate for installations where it is necessary to maintain a constant water surface elevation. Where designs provide a range within which the water surface can fluctuate, or where fluctuation throughout the proportional band can be tolerated, proportional control becomes appropriate. For example, upstream proportionally controlled gates are most appropriate for flood control structures, because designs usually include an operating range compatible with the proportional band. At such installations the proportional action of the gate combines with storage that increases rapidly as the controlling water surface rises to

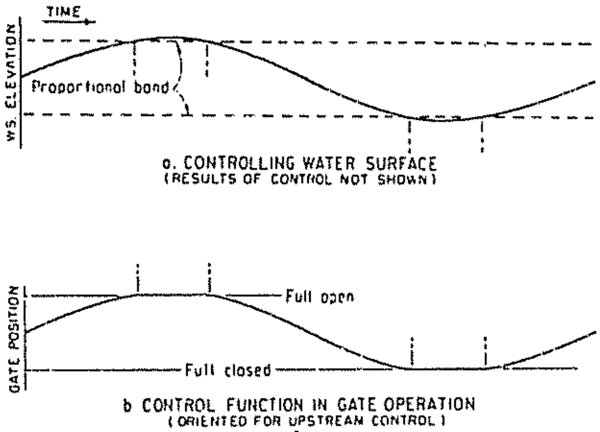


Figure 9.–Proportional control.

provide the usually desired function of retarding flow from storm runoff. Flow through the gate is related to the amount of water impounded rather than inflow at any specific time.

Very little information is available on past usage of proportional controls for automating canal control structures. Except for the limitations imposed by the need for a proportional band, proportional control is appropriate for either upstream (supply) or downstream (demand) type of operation. Adaptability to combination with dead time (lag) and reset modes of control make it most appropriate for downstream control. Resulting operation is inherently responsive to changes of any size at any point in a system, and has a high degree of safety against overtopping the canal in emergency conditions.

The width of the proportional band and its associated range of controlled water surface variation is a function of gain factor (ratio of output to e). In canal operation, an inverse relationship exists between gain factor and stability of flow. Stability increases as gain factor decreases. These relationships work against each other to create stability problems when a narrow proportional band is desired. The width of proportional band required to achieve stable flow in canals often becomes unacceptable for gravity deliveries. Proportional control without reset also reduces canal capacity.

4. Proportional Plus Reset Control

Proportional control can be made more acceptable for open systems with gravity deliveries by the addition of a reset function to eliminate the proportional deviation. Addition of the reset function does not eliminate variations of the controlled water surface elevation that occur when flows change, but it does return this water surface to the elevation that existed before the change. Minor differences in position of the controlled gate account for the characteristic differences shown in figure 10 between water surfaces controlled by proportional control and those controlled by proportional plus reset control.

By recovering the controlled water surface to the original target depth, proportional plus reset control makes overall operation of the canal similar to traditional operation in that flow changes also require appreciable changes in the storage of each check reach. Gates at the upstream end of the canal will make larger adjustments to accommodate these storage changes. Water surface fluctuations will be temporary, disappearing as the reset function takes effect. As long as incremental flow changes do not exceed 20 percent of design capacity, controlled water surface fluctuations are expected to be no larger than those that occur from manual operation, and automatic operation is expected to be highly responsive to changes anywhere in the system. However, canals operated by proportional plus reset are not as safe against overtopping as canals operated by proportional control because decreased demand causes upsurges similar to the downsurges caused by increased demand. The possibility of power outages on systems with large pump deliveries may require additional canal freeboard.

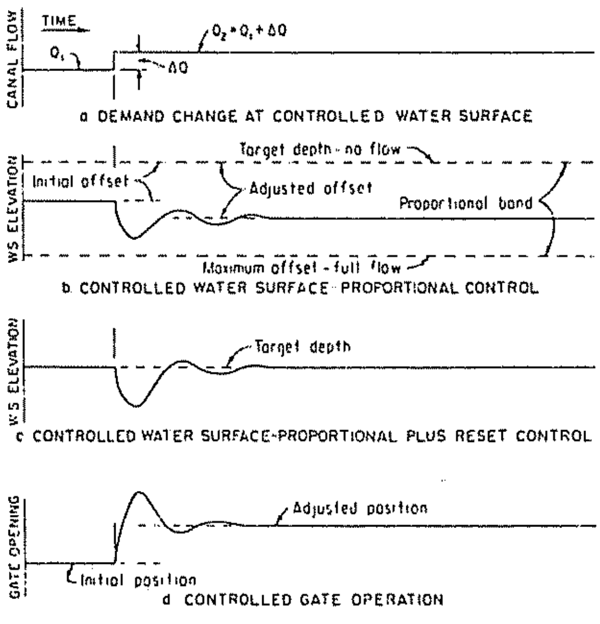


Figure 10.—Characteristic results of control by proportional and proportional plus reset modes oriented for downstream control

Remote Control

1. Manual Operation

The capability for remotely operating control structures often results in improved operation of water conveyance systems. Any installation that provides the capability for remote control should also include telemetering of sufficient data so that the operator can determine the results of adjustments and also be alerted to the development of undesirable or dangerous conditions in the system.

Operation by remote manual control can be quite similar to operation by local manual control. Schedules for operation of the various control structures should be developed based on experience. However, the additional flexibility of controlling all structures from a master station permits a high degree of coordination in adjusting structures. Properly utilized, this coordination can greatly reduce the time required to accomplish flow changes in many conveyance systems.

2. Centralized Computer

Centralized computer operation of remote control systems becomes desirable on installations where numerous adjustments must be made within a short period of time or where close attendance by an operator is required over a long period of time. Additional equipment to accomplish centralized computer operation is usually located at the master station. This equipment is energized to perform control functions either at predetermined times or in response to conditions interpreted from telemetered data.

While special equipment can be assembled to perform some individual operations automatically, an interface with a computer greatly increases the flexibility of controls for accommodating numerous and varied control functions. In addition to programing that accomplishes selected control functions at predetermined times, a computer can also be programed to interpret telemetered data and perform complicated control functions. Because of this extreme flexibility, the adaptability of a computer in providing a programable master supervisory control (PMSC) appears to be limited only by the ingenuity and imagination of the designer.

3. Equipment

Commercial equipment is generally available for manually performing remote control functions from a master station. Commercial equipment is also available for telemetering data concerning most of the conditions encountered, and for automatically performing many of the control functions required. Special arrangements of equipment can usually be assembled from commercially available components to accommodate those situations where equipment is not readily available. Some situations will require development of new equipment and specialized computer programing.

A major portion of cost for a remote control system is represented by the communication channels that are required between the master station and all remote stations. The type and number of circuits required are determined by the manner in which the controls are to be operated and by the amount of data that is to be telemetered. Direct-current (d-c) channels are suitable for sending impulse-type signals and usually require a separate channel for each set of data. Voice grade channels with tone transmitting equipment can accommodate large quantities of data.

Alternatives for providing communication channels include direct wire, radio, and microwave. For most reliable operation, direct wire systems, whether buried or overhead, should be dedicated exclusively to the control system. Radio and microwave systems may require repeater stations where distances are great or where adverse topographic conditions exist. Selection of the type of communication system is usually based on economic factors. A completely separate backup communications system is always desirable and strongly recommended for extensive conveyance systems.

General Applications

Open Channel Systems

Successful applications of feedback controls for the automatic operation of open channel conveyance systems are in use on Reclamation projects in the following categories:

1. Two-position control of pumps oriented for both upstream and downstream control
2. Upstream control of the sluice gates in diversion dams and the inlet gates or valves of headworks structures by both floating and proportional modes to maintain steady diversion flow
3. Upstream control of wasteway gates in canals and spillway control gates in dams by both floating and proportional modes to pass excess water
4. Upstream floating control of gates in individual canal control structures and in a series of canal control structures to pass canal flows through the structures while maintaining desired upstream water surfaces at the other structures in the system

5. Downstream floating control of gates in individual canal control turnouts and headworks structures to maintain steady flow through measuring structures
6. Downstream proportional reset control of canal check gates to match the conveyance flow with canalside demands

Because of simplicity, two-position controls are probably the most widely used mode of feedback control. The ON-OFF characteristics of these controls make them most appropriate for the operation of pumps. Oriented for downstream control, they operate pumps to maintain the water surfaces in reservoirs at the elevations desired for operating distribution and conveyance systems. Oriented for upstream control, they are commonly used to operate sump pumps to remove unwanted accumulations of water from structures and drains. The operating ranges of pumps in multiple-pump installation are often overlapped and staggered to increase flexibility in total pump discharge. These controllers are usually activated by either electrical probe or float-operated switches.

There are very few successful applications of unmodified single-speed floating controls on Reclamation projects. Their use appears to be limited to installations where slower than normal speed motors have been added to gates originally installed for manual operation. Floating controls are usually activated by either probe or float-operated switches. The antihunt function is much easier to perform when float-operated switches are used.

The Friant-Kern Canal on the Central Valley Project in California and the West Canal on the Columbia Basin Project in Washington represent some of the most extensive applications of automatic canal operation among the various Reclamation projects. Both of these canals utilize a large number of "little man" controllers that have been developed by the operators. The term "little man" has been applied at different times to such a wide variety of installations that its definition is somewhat obscure. In general, the term applies to single-stage floating controllers modified by SOT/SRT and often includes an antihunt device. "Little man" controllers have also been assembled that include (1) two or three stages of floating controls, (2) a 1-revolution-per-day motor that raises or lowers the target depth a fixed amount each day for filling or unwatering a canal, and (3) a 24-hour clock that can be set to open a turnout at some predetermined time.

Operators on the Friant-Kern Canal pioneered the development of "little man" controls. The development of similar controls on the Columbia Basin Project was completely independent of the earlier effort. Both developments perform almost identical functions but with considerably different equipment. Schematic diagrams of this equipment are shown in figures 11 and 12. Both of these developments, operated by floats, disclosed a need for an antihunt device.

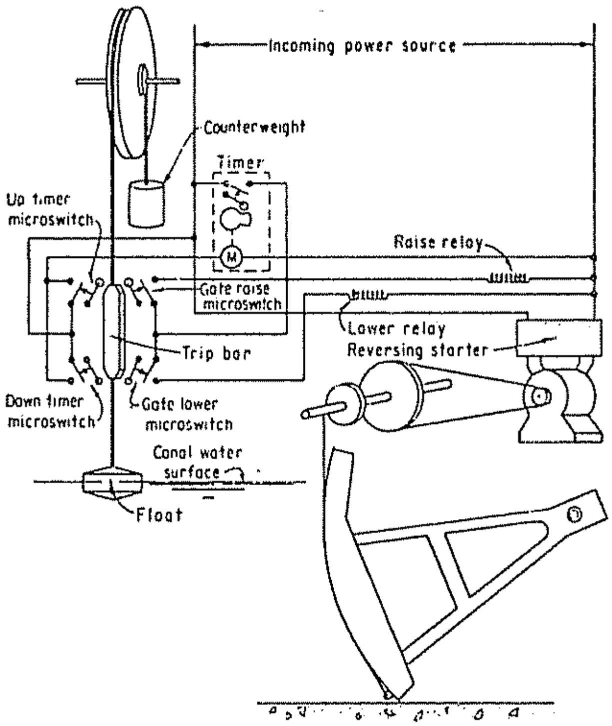


Figure 11.–Schematic diagram for a Columbia Basin type little man controller.

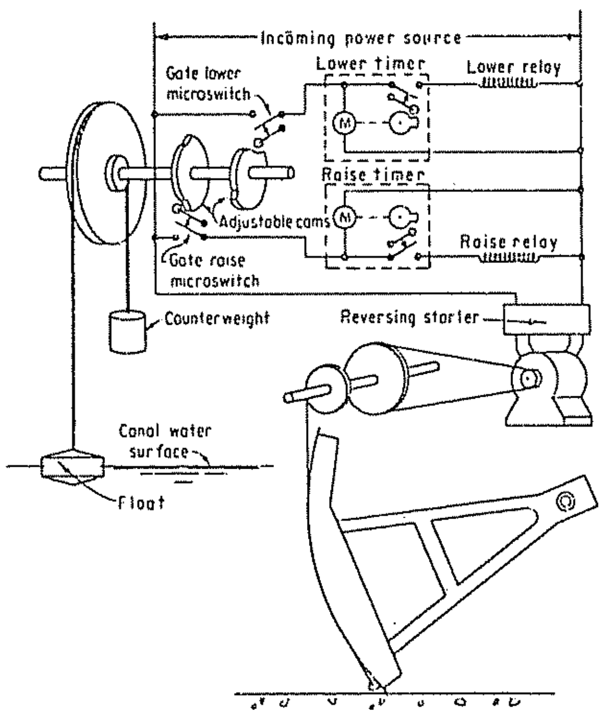


Figure 12.–Schematic diagram for a Friant-Kern type little man controller.

Because floating controls are appropriate for situations where there is no appreciable lag, they are best suited for the control of water surfaces that are adjacent to the controlling gates. Where floating controls do not achieve satisfactory control, the failure is often due to excessive lag. Lag increases as the distance between the controlled water surface and the controlling gate increases. Lag is created by a controlling gate that moves too slowly, or by a sensed water surface that is damped excessively in a stilling well. The corrective actions of an antihunt device and the use of multiple-stage controllers can make some allowance for lag. But there are many situations in which the use of floating controls is not appropriate.

As a general rule, floating control can be considered appropriate for upstream control but not for downstream control. An exception is made to this rule for downstream control when the controlled water surface is located sufficiently close to the controlling gate so that the effects of lag are not objectionable.

Some attempts have been made to operate a series of canal control structures by downstream floating controls of the "little man" type. While most of these attempts have been unsuccessful, a degree of control of Friant-Kern Canal has been achieved that operators have tolerated. Downstream control equipment is installed on the last three check structures, downstream from a regulating reservoir, to control water surfaces immediately downstream from the structures. Adjustment of target depth is required for any significant flow change. The other check structures, upstream from the regulating reservoir, use upstream control.

The Bureau of Reclamation first became interested in applying downstream control in the 1960's. Through a research contract with the University of California at Berkeley, an investigation of the downstream control concept was sponsored. Additional research by the university and the Bureau of Reclamation led to the development of a controller called the electronic filter level offset (EL-FLO). The EL-FLO controller is based on proportional and reset modes of control.

EL-FLO controllers have been installed on two canals in California - the Coalinga and the Corning.

At the Coalinga Canal, upstream control with local controllers and a regulating reservoir to eliminate waste was originally planned. Later studies indicated that downstream control eliminated the need for the planned regulating reservoir, resulting in substantial savings.

Water is diverted from the California Aqueduct and lifted 180 feet into the Coalinga Canal via the Pleasant Valley Pumping Plant. The nine pumps of different sizes have a total capacity of 1,185 cubic feet per second (ft^3/s). The canal is concrete lined and 11.6 miles long. The canal and pumping plant are operated by the Westlands Water District. Flow is controlled by gates at three locations. Both gravity and pump systems distribute water from the canal at nine different points, sharing common pumps.

EL-FLO controllers were installed during the summer of 1975 to control two gates. The third gate will be placed under EL-FLO control when pump controller equipment is installed at Pleasant Valley Pumping Plant.

The Corning Canal, which uses water diverted from the Sacramento River near Red Bluff, California, is the other canal where EL-FLO control has been applied. Water is lifted 71 feet into the canal at the Corning Pumping Plant where six pump units of different sizes are housed. Some of the units are operated automatically to provide a flow which will approximately match the canalside demands. The Corning Canal is a 21-mile-long, earth-lined canal with a capacity of 500 ft^3/s. Canal flow is regulated by 12 gates spaced at intervals along the canal. The canal has 29 canalside turnouts. Twenty-six of the turnouts are pump type, of which seven are automatic. Most of the turnout valves to farmers' lands are operated by them.

During the first few years of operation when canalside demands were small, the Corning Canal was operated manually. Manual operation was complicated by the addition of automated pipe distribution systems having pressure pipe laterals. These automated laterals are essentially demand systems but their efficiency was limited by the capability of the canal to respond. Workers who manually operated the canal could not satisfactorily predict diversions and match canal flows to demands.

The first modification to aid operation was automation of the Corning Canal Pumping Plant and the settling basin, which is the intake for the pumping plant. Later, locally designed controllers were installed at all canal gates pending the development of the new method of automatic downstream control (EL-FLO controller).

After significant progress had been made in the development of the EL-FLO controllers, the equipment was installed to control all gates on the Corning Canal. The installation was completed late in the summer of 1975.

Reclamation has for many years installed upstream proportional control equipment on spillway control gates of large dams and on sluice gates of diversion dams where automatic operation is desired. Gate operation can be either electrically or hydraulically powered. Hydraulically powered systems are presently considered to be the most reliable. Electrically powered systems are activated by float-operated switching equipment that is very similar to the equipment required for floating control. Proportional action is provided by a traveling crosshead interconnected with the gate to raise the switches as the gate opens, see figure 13. Hydraulic systems use large floats and counterweights to unbalance forces that open or close the gates in response to water surface movements in the float-wells. Control equipment includes weirs and orifices that are designed to control rates of flow into and out of the floatwells at the rates required to provide proportional action in the gate, see figure 14. Counterweights may be attached either to the operating shaft of the gate or behind the pin bearing.

Pipe Systems

Several factors make complete automation more readily attainable for pipe systems than for open channels. The inherent downstream control of a pipe system in which sufficient pressure is maintained to deliver full capacity is a very influential factor. Another very important factor is the relative simplicity of accommodating surges by increasing the strength of the pipe. Physical enlargement of the facilities by surge tanks or other devices is required only at isolated locations. To all of these factors must be added the fact that commercial equipment is readily available for automatic control of pipe systems. Much of this commercial equipment has been developed to meet specific needs.

Recently constructed Reclamation pipe systems for both conveyance and distribution provide a high degree of automatic control utilizing feedback controls widely. Older systems are also being automated. Full-pressure systems utilize feedback controls widely to achieve virtually complete automatic operation. While no Reclamation pipe systems are computer-controlled at this time, this type operation is contemplated for the Southern Nevada Water Project and the Yuma Desalting Plant.

Design of these control systems requires a thorough knowledge of both the conveyance and the control functions performed by automatic equipment. Investigations often reveal the need for special requirements or limitations. However, designers confidently approach automation for pipe systems with the attitude that any automatic operation desired by operators can be provided.

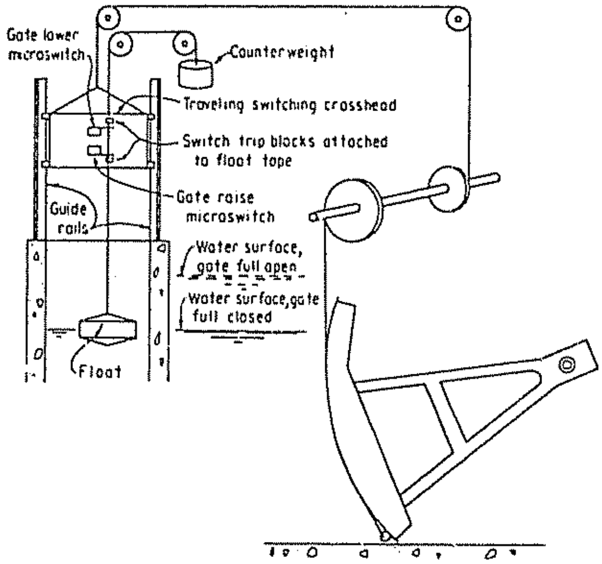


Figure 13. - Schematic diagram of equipment for proportional upstream control of electrically powered gate.

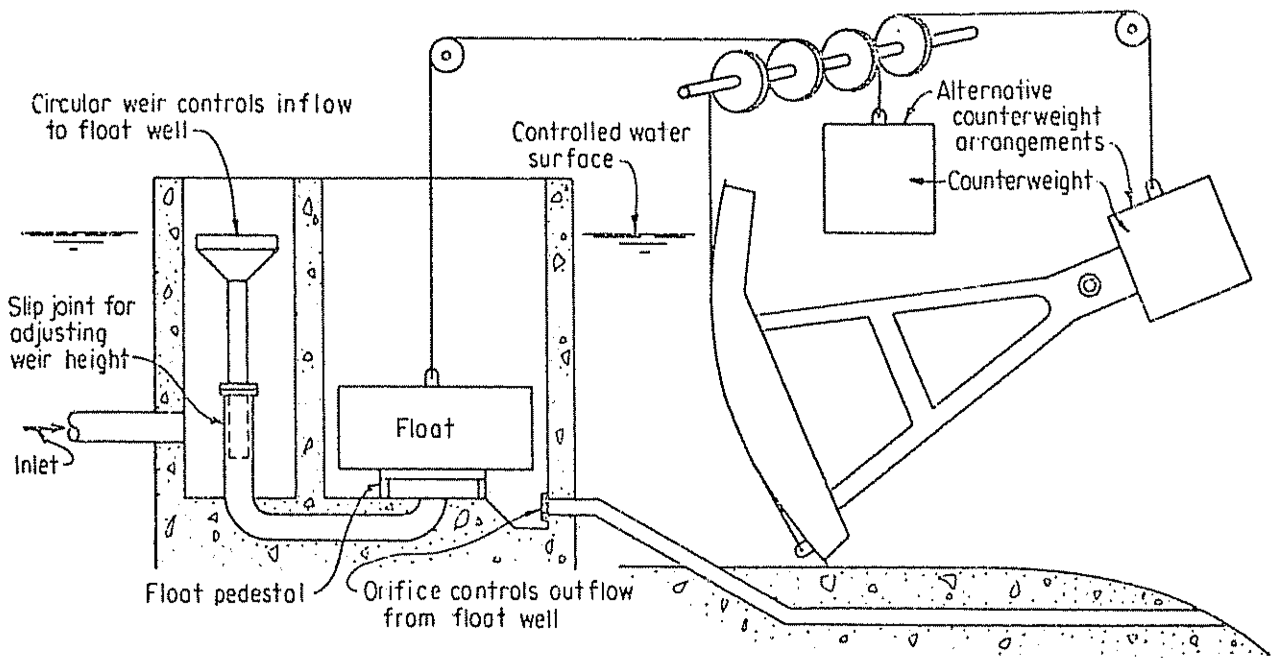
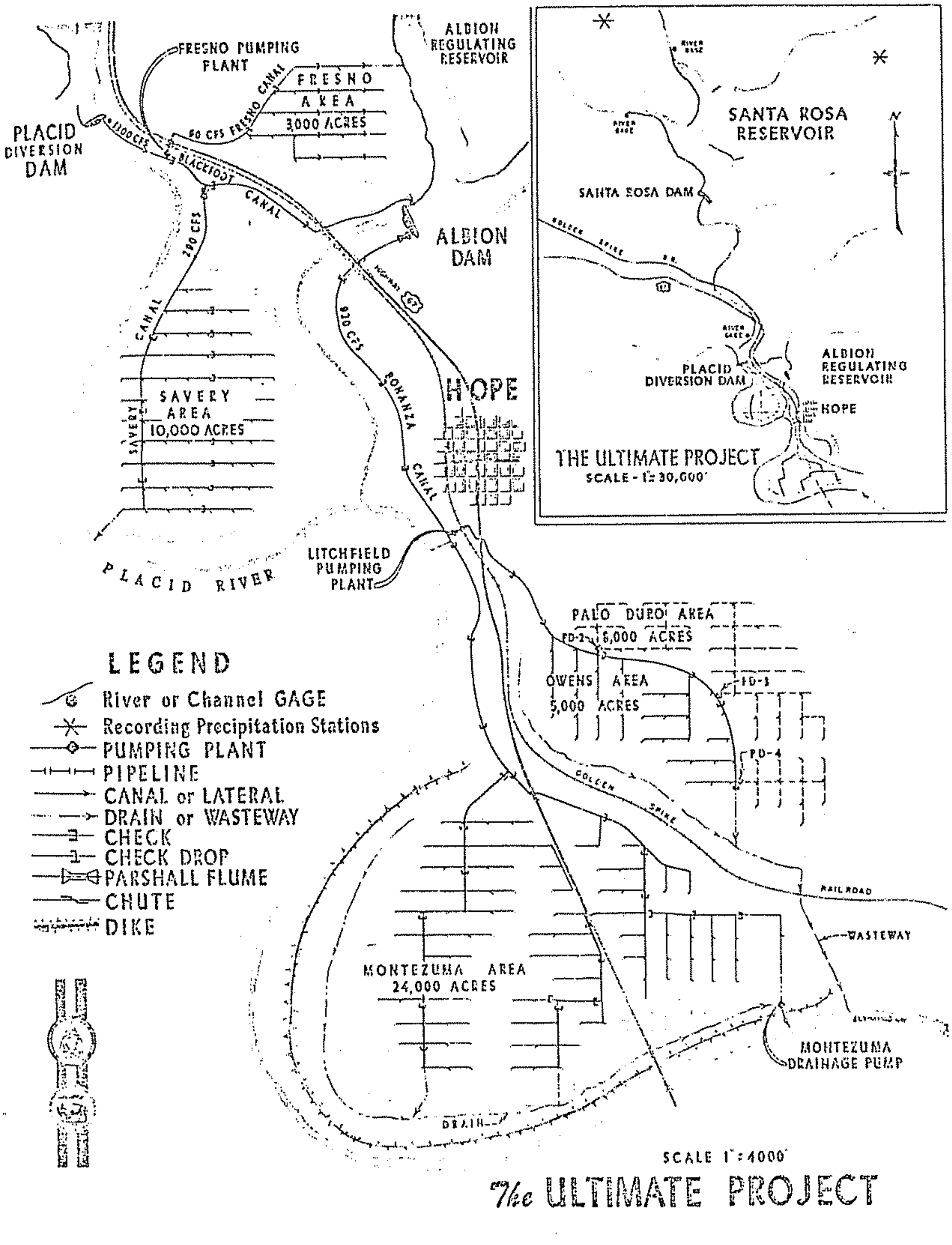


Figure 14. - Schematic diagram of equipment for upstream control of hydraulically powered gate.


FRESNO PUMPING PLANT
ALBION REGULATING RESERVOIR
FRESNO AREA 3000 ACRES
FRESNO CANAL
PLACID DIVERSION DAM
1100 CFS
BLACKFOOT CANAL
290 CFS
ALBION DAM
HIGHWAY 67
920 CFS
BONANZA CANAL
SAVERY AREA 10,000 ACRES
SAVERY
CANAL
HOPE
PLACID RIVER
LITCHFIELD PUMPING PLANT
PALO DURO AREA 6,000 ACRES
PD-2
PD-3
PD-4
OWENS AREA 5,000 ACRES
GOLDEN SPIKE
RAIL ROAD
WASTEWAY
MONTEZUMA AREA 24,000 ACRES
MONTEZUMA DRAINAGE PUMP
DRAIN
LEGEND
River or Channel GAGE
Recording Precipitation Stations
PUMPING PLANT
PIPELINE
CANAL or LATERAL
DRAIN or WASTEWAY
CHECK
CHECK DROP
PARSHALL FLUME
CHUTE
DIKE
SANTA ROSA RESERVOIR
SANTA ROSA DAM
GOLDEN SPIKE R.R.
PLACID DIVERSION DAM
ALBION REGULATING RESERVOIR
HOPE
THE ULTIMATE PROJECT
SCALE - 1" = 30,000'
SCALE 1" = 4000'
The ULTIMATE PROJECT